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BIBLIOGRAPHY

of the

HUMAN PROTECTIVE SYSTEMS DIVISION
(formerly the Biosciences Division)

1986 to Present

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and
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PREFACE

This publication is the 2nd Edition of the divisional bibliography. The 1st Edition, published in 1992, was entitled "Bibliography of the Biosciences Division – 1986 to Present". In 1993, a reorganization of the divisions at DCIEM took place which resulted in the Operational Medicine Section and its program moving to another division and the division being renamed the "Human Protective Systems Division". Now, further changes within DCIEM have occurred as the result of the re-engineering of the Research & Development Program within the Department of National Defence. Divisions within Research Establishments have disappeared and the R&D program is now to be delivered by Thrusts which are directly related to military requirements.

Limitation in the fonts used in the 1st Edition have now been overcome and it is hoped that we have managed to capture all the scientific nomenclature present in the original abstracts. As before, this bibliography was produced on Macintosh computers using "EndNote Plus" with the final page proofs being produced in Microsoft Word 5.1. Thanks are due to all the scientists in the Division for proofreading their individual contributions.

As I look at this impressive collection of scientific and technical output, I am very proud to have been associated with, and to have had some influence in shaping the direction of the program reported here. While it may be more difficult to capture in a publication such as this, I am confident that the scientists in my former division will continue to be noted for their scientific excellence as our means of delivery of the Research & Development program to our clients, the Canadian Forces, evolves.

Kenneth N. Ackles, Ph.D.
formerly, Director,
Human Protective Systems Division
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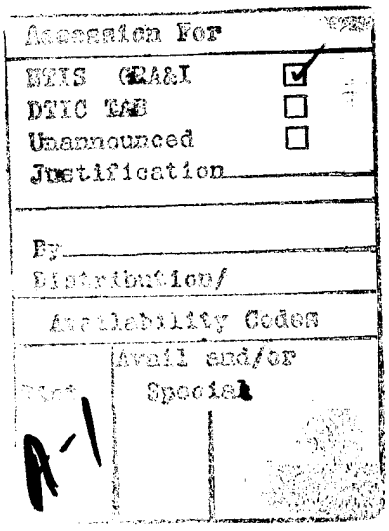

LIFE SUPPORT SYSTEMS SECTION

51C2

Aerospace Life Sciences and Life Support Systems

1986

Fowler, B., Hamilton, K., & Porlier, G. (1986). **Effects of alcohol and amphetamine on inert gas narcosis.** *Undersea Biomed. Res., 13*(3), 345-354.

Abstract The effects of ethyl alcohol (1 ml/kg body weight), dextroamphetamine (15 mg), and nitrous oxide (20%) on reaction time were investigated in 6 subjects with a 2-, 3-, and 4-choice serial reaction time task. Each drug was assessed separately and in combination with nitrous oxide. The error rate was held constant. Neither ethanol and nitrous oxide nor amphetamine and nitrous oxide influenced the slope of the Hick-Hyman function, but the former combination increased the intercept while the latter decreased it. The drugs, either alone or in combination, shifted the frequency distributions of the reaction times as a whole, rather than modifying either their shapes or the pattern of the response latencies around an error. These results indicate that the drugs have a common pattern of effects on reaction time and that alcohol exacerbates narcosis while amphetamine ameliorates it. This is interpreted as support for the view that narcosis causes a nonspecific slowing of information processing by decreasing arousal.

Goodman, J., & Goodman, L. S. (1986). **Exercise prescription for the sedentary adult.** In R. J. Shephard & P. Welsh (Eds.), *Current Therapy in Sports Medicine, 1985 - 1986.* Toronto,: B.C. Decker Inc.

Abstract Exercise is regularly employed to screen for the presence of disease in asymptomatic patients, and as a modality in rehabilitation. However, relatively few practitioners prescribe exercise as a method of primary prevention in the obese, borderline hypertensive, sedentary, or borderline diabetic adult patient. Nor is the value of exercise exploited in the development of positive health behavior and the prevention of degenerative diseases.

This chapter will outline the physiologic rationale as well as the current state-of-the-art methodology of exercise prescription for sedentary adults.

Hamilton, K., Fowler, B., & Porlier, G. (1986). **A study on the effects of nitrogen narcosis on diver performance.** In *Proceedings of the 19th Annual Meeting of the Human Factors Association of Canada.* (pp. 67-70). Vancouver, B.C.: Human Factors Association of Canada.

Abstract A number of studies have used nitrous oxide to investigate nitrogen narcosis in humans at the surface. However, it has not been clearly established that nitrous oxide and hyperbaric air produce identical effects on behaviour. Accordingly, two experiments were conducted to ascertain if the effects of alcohol (ALC=1.5 mg/kg) and dextroamphetamine (DEX=15 mg) in combination with hyperbaric air were comparable to those obtained with nitrous oxide in previous surface studies. In each experiment, 8 subjects performed a serial 2, 3 and 4 choice-reaction time task at a pressure of 6.4 ATA. The results indicated that ALC adds to the impairment produced by narcosis and DEX has an ameliorating effect. These findings confirm the hypothesis that hyperbaric air and nitrous oxide produce equivalent qualitative effects on behaviour, probably through the sane mechanisms. The present study also demonstrates the validity and practicality of using nitrous oxide to investigate the effects and causes of inert gas narcosis in humans safely and economically on the surface.

Hamilton, K., Porlier, G., Landolt, J., Fraser, W., & Fowler, B. (1986). **Effects of inert gas narcosis on the vestibular ocular reflex.** *Undersea Biomed. Res., 13*(3), 355-359.

Abstract A study was conducted to examine the vestibular ocular reflex (VOR) during narcosis. The slow phase velocity of the nystagmus was measured in six subjects by means of electronystagmography during the inhalation of 25% nitrous oxide. It was found that nitrous oxide increased the velocity of the slow phase component of the VOR by approximately 50%. This result indicates that the gain of the VOR is effectively increased during nitrous oxide induced narcosis. It appears that the vestibular end organs and/or the central pathways controlling nystagmus are affected by nitrous oxide and this may be a reason for the disruption in balance associated with inert gas narcosis.

Henderson, D. L., & Tikuisis, P. (1986). ***Investigation of oxygen pre-breathing at 8000 ft vs. ground level prior to altitude exposure.*** (DCIEM 86-C-19). Defence and Civil Institute of Environmental Medicine.

Abstract Denitrogenation of body tissues by breathing 100% oxygen with an oronasal mask at ground level for 30 minutes is routinely used in the Canadian Forces to protect aircrew from decompression sickness (DCS) during altitude exposures above 18,000 feet in the course of Aeromedical Training (AMT). Despite this measure plus limiting the period above 25,000 ft to 20 minutes, a total of 10-12 cases of altitude DCS per year are still being reported by the hypobaric chambers utilized by the CF for AMT. A simple trial was conducted. Results have revealed marked inter-individual differences in the volume of nitrogen eliminated and the mean values do not support a statistically significant difference between oxygen prebreathing at ground level versus 8,000 ft.

Ward, C. A., Koheil, A., McCullough, D., Johnson, W. R., & Fraser, W. D. (1986). **Activation of complement at plasma-air or serum-air interface of rabbits.** *J. Appl. Physiol., 60*(5), 1651-1658.

Abstract The possibility of the air-plasma interface giving rise to complement activation is investigated. After incubation of the plasma of a group of rabbits with zymosan and measurement of the degree of autologous polymorphonuclear leukocyte aggregation that follows the injection of a sample of the incubated plasma into a leukocyte suspension, it is found that the rabbits can be divided into two groups, sensitive and insensitive, depending on the degree of leukocytes aggregation. For the sensitive group it is found that both the plasma-air interface and the serum-air interface give rise to significant leukocyte aggregation. If the animal is decomplemented before the plasma is incubated in the presence of the air interface, there is no longer any significant leukocyte aggregation. It would appear that the complement system is activated by the presence of the air interface in plasma, but that fibrinogen does not play a pivotal role in the process.

1987

Buick, F., & Porlier, J. A. G. (1987). ***Tactical Life Support System: Design considerations for protection against high +Gz.*** (DCIEM 87-TR-21). Defence and Civil Institute of Environmental Medicine.

Abstract Advanced tactical aircraft are able to produce high levels of +Gz at onset rates in excess of +10 Gz/sec. One of the aims of the Tactical Life Support System programme is to improve the protection against the physiological problems occurring during +Gz. The importance of the anti-G suit and positive pressure breathing to +Gz tolerance are reviewed with recommendations intended to improve their effectiveness.

Fowler, B., Hamilton, H., & Porlier, G. (1987). **Interactions between ethanol, amphetamine and inert gas narcosis on the performance of a memory scanning task.** In A. A. Bove, A. J. Bachrach, & J. L.J. Greenbaum (Eds.), *Underwater Physiology IX, Proceedings of the Ninth International Symposium on Underwater and Hyperbaric Physiology.* (pp. 583-588). Bethesda, MD: Undersea and Hyperbaric Medical Society.

Abstract It is well known that inert gas narcosis disrupts performance on a variety of tasks. Lately, there has been a good deal of interest in how drugs may influence this impairment in humans for both practical and theoretical reasons. In the former instance, the concern is generated by the increase in drug usage and the consequences on the operational safety of divers. In the latter case, there exists a distinct possibility that patterns of drug effects may provide insight into the mechanisms underlying narcosis. In this regard, it has been demonstrated that both nitrous oxide and hyperbaric air increase the intercept but not the slope of the Hick-Hyman choice reaction time function. It has also been found in the same studies that ethanol exacerbates this increase while amphetamine ameliorates it. These experiments used an identical serial choice reaction time task. The next step was to determine whether or not these findings could be generalized to other tasks. This hypothesis was investigated in an experiment designed to assess performance with Sternberg's short-memory scanning paradigm.

In the Sternberg's task, a set of stimuli is presented followed by a test stimulus. Reaction time to the inclusion or exclusion of the test stimulus in the set is a linear function of set size (4). Six subjects were used and digit set sizes of 1, 3, and 5 were presented under each of the following conditions: placebo, nitrous oxide (20%), ethanol (1.5 ml/kg of body weight), amphetamine (15 mg), nitrous oxide combined with ethanol, and nitrous oxide combined with amphetamine. Error rate was controlled to less than 2% and correct reaction times were analysed. Linear functions were fitted separately to the included and excluded digits in each condition. Analyses of variance revealed that the intercepts of the reaction time function were significant among the conditions tested while the slopes were not affected. Tests on these data showed that nitrous oxide increased the intercept, ethanol exacerbated this increase and amphetamine ameliorated it ($p < 0.05$ in all cases).

Fowler, B., Hendricks, P., & Porlier, G. (1987). **Effects of inert gas narcosis on rehearsal strategy in a learning task.** *Undersea Biomed. Res., 14*(6), 469-476.

Abstract Two experiments were conducted to examine the effects of 35% nitrous oxide (N20) on rehearsal strategy while learning a list of words in a free-recall paradigm. In experiment 1, the subjects learned the list while rehearsing the words aloud. Learning was slowed and an analysis of the recorded rehearsal protocols revealed a decrease in the overall rate of rehearsal. In addition, there was a decrease in both the number of words rehearsed together and the proportion of words rehearsed from earlier serial positions in the list. In experiment 2, the subjects were required to follow a different rehearsal protocol which was identical for both N20 and the air-breathing control. They had no difficulty following this protocol, but learning was still slowed.

Fowler, B., Kelso, B., Landolt, J. P., & Porlier, G. (1987). **The effects of hypoxia on P300 and reaction time.** In *Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine,* AGARD-CP-432, (pp. 33-1 - 33-10). AGARD, Paris, France.

Abstract This experiment investigated the effects of three levels of arterial oxyhemoglobin saturation (SaO_2 of 75%, 70%

and 65%) on reaction time (RT) and P300 latency and amplitude. Ten subjects responded to visually presented male or female names in an oddball paradigm with accuracy controlled at a high level. Hypoxia increased both RT and P300 latency in a dose-related manner and these variables were strongly correlated. Hypoxia did not influence P300 amplitude. The increase in P300 latency is interpreted as further evidence that hypoxia slows stimulus evaluation processes and that, under the right circumstances, P300 could be used to index the effects of hypoxia on performance.

Fowler, B., Taylor, M., & Porlier, G. (1987). **The effects of hypoxia on reaction time and movement time components of a perceptual-motor task.** *Ergonomics, 30,* 1475-1485.

Abstract It has previously been demonstrated that hypoxia disrupts performance on a visual SCRT (serial choice response time) task. Two experiments were conducted to examine further the nature of this disruption. Hypoxia was induced with low oxygen mixtures and SaO_2 (arterial oxyhaemoglobin saturation) was held at a level equivalent to an altitude of approximately 4700 m. In experiment 1, choice reaction time was measured with a version of the SCRT task that eliminated movement time. Hypoxia increased the intercept but not the slope of the Hick-Hyman function. In experiment 2, movement time was measured with a reciprocal tapping task. Hypoxia increased not only the slope of Fitts' function but also the slopes produced when target width and movement amplitude were analysed separately. In both experiments the error rate was held constant. These results indicate that hypoxia disrupts the reaction time and movement time components of SCRT performance. It is proposed that reaction time is slowed rather than 'blocked' and that decreased brightness sensitivity contributes to this slowing but the choice processing stage does not. Movement time is also slowed due to a disruption of both the aiming and ballistic processes controlling movement.

Fraser, W. D., Black, N., Eastman, D. E., & Landolt, J. P. (1987). **The effect of mild hypoxia on the vestibular evoked response.** In *Electric and Magnetic Activity of the Central Nervous System: Research and Clinical Applications in Aerospace Medicine,* AGARD-CP-432, (pp. 16-1 - 16-7). AGARD, Paris France.

Abstract The effect of hypoxia on the long-latency vestibular evoked response (VSER) was examined in eight sitting subjects who underwent intermittent 0.1 Hz sinusoidal rotation in complete darkness, while fixating on a small target light that rotated with the subject. Evoked responses were recorded during 10 minutes of rotational stimulation after breathing each gas mixture for a minimum of 25 minutes. For intermittent clockwise (CW) rotation in the horizontal plane, a reproducible negative potential (-28.7 ± 2.3 μV) (mean ± SEM) developed at electrode sites located between the vertex and the "linked" ears during air breathing conditions. It peaked close to the point of maximum velocity of the sinusoidal stimulus. This negative cortical potential decreased (i.e., it became less negative) with respect to the air control by 25.4% ($P < 0.01$) when the subjects were exposed, to a 16.7% oxygen breathing mixture (altitude equivalent of 1900 m) . No effect was seen with 18.7% (910 m) and 14.4% (2780 m) oxygen breathing mixtures. For intermittent counterclockwise (CCW) rotation, a positive potential (30.1 ± 3.7 μV) developed, during air breathing, between the vertex and the linked ears. This amplitude decreased by 18.9% when breathing both the 18.7% and 16.6% oxygen gas mixtures ($P < 0.01$), and by 17.9% for a 14.4% oxygen mixture ($P < 0.05$) compared to the standard, air. These results indicate that the cortical processing of vestibular sensations may be affected even under very mild hypoxic conditions. Animal studies have in-

dicated that the levels of hypoxia used in this study can significantly alter neurotransmitter metabolism in brain tissue. Modifications in neurotransmitter synthesis and concentration by the hypoxic conditions may explain the susceptibility of cortical processing of sensory information to very mild hypoxia. Compensatory changes in cerebral blood flow and neurotransmitter synthesis may be responsible for the reduced effect under the more severe hypoxic conditions.

Fraser, W. D., Paul, M. A., Eastman, D., & Porlier, G. (1987). **Decrement in postural control during mild hypobaric hypoxia.** *Aviat. Space Environ. Med., 58,* 768-772.

Abstract The effects of mild hypoxia on the postural control system of 39 naive subjects were examined by measuring the postural sway with a Kistler force platform, at ground level and at one of four simulated altitudes: 1,521 m (5,000 ft), 2,438 m (8,000 ft), 3,048 m (10,000 ft), or 3,658 m (12,000 ft). The total sway increased above the ground level controls for the 1,521 m, 2,438 m, and 3,048 m exposures ($p \leq 0.005$) as did the sway at the lowest measurable frequency ($p \leq 0.002$), but no change in sway was seen in those subjects exposed to 3,658 m as compared to ground level values. Significant interaction between altitude and exposure was observed at $p \leq 0.04$, reflecting the definite effect at the lower altitudes and the lack of an effect at the higher altitude. The multiple comparison test indicated no difference between the responses at 1,524 m, 2,438 m, and 3,048 m. Both arterial oxygen saturation, S_aO_2, and the end-tidal oxygen partial pressure, $P_{et}O_2$, decreased in relation to the test altitudes with a statistically significant interaction between altitude and $P_{et}O_2$ ($p \leq 0.02$), and S_aO_2 ($p \leq 0.005$). There was no significant interaction between altitude and end-tidal carbon dioxide partial pressure ($p = 0.4853$). The postural control mechanisms, as an integrative functional unit, are very sensitive to acute mild hypoxia. Arguments are advanced to indicate that intervention of compensatory mechanisms at higher altitudes may explain the recovery of postural stability at 3,658 m.

Howard, I. P., Cheung, B., & Landolt, J. P. (1987). **Influence of vection axis and body posture on visually-induced self-rotation and tilt.** In *Motion Cues in Flight Simulation and Simulator Induced Sickness,* AGARD-CP-433, (pp. 15-1 - 15-8). AGARD, Paris, France.

Abstract Yaw vection is induced by a scene rotating about the spinal axis (z axis), pitch vection by a scene rotating about an axis in the mid-frontal plane (y axis) and roll vection by a scene rotating about an axis parallel to the line of sight (x axis). Each of these axes can be vertical or horizontal, making six conditions in all, of which only four have been studied previously. We studied vection and illusory body tilt under all six conditions, with a full rotating field, reduced somesthetic cues and in a situation in which body rotation could occur. Yaw vection around a vertical axis was strongest. Forward pitch vection was stronger than backward pitch vection. Contrary to previous reports, for most subjects backward illusory tilt was much stronger than forward illusory tilt. Two subjects experienced 360° body rotation in the horizontal-pitch condition. The direction of pitch axis asymmetry was found to be consistent and not related to the asymmetry of vertical optokinetic nystagmus.

Howard, I. P., Ohmi, M., Simpson, W., & Landolt, J. P. (1987). **Vection and the spatial disposition of competing moving displays.** In *Motion Cues in Flight Simulation and Simulator Induced Sickness,* AGARD-CP-433, (pp. 16-1 - 16-8). AGARD, Paris, France.

Abstract In Experiment 1 we investigated the relative effectiveness of two super-

imposed displays in generating circular vection as a function of (i) the separation in depth between them, (ii) their perceived relative distances, and (iii) which display was in the plane of focus. Circularvection was found to be governed by the display that was perceived to be more distant, even when it was actually nearer. Vection was not affected by whether the near or far display was in the plane of focus, nor by which display was fixated or pursued by the eyes. In Experiment 2 we asked whether the generally held belief that vection is induced most effectively by the peripheral stimuli is due to an artificial effect of perceived distance. The experiment assessed the separate contributions of foreground-background and central-peripheral placement of competing displays. It was found that both factors contribute in an interactive way to the experience of vection. In Experiment 3 we investigated how linear forward vection induced by a looming visual display is affected by the near-far relationships of competing displays.

Khalsa, S. B. S., Tomlinson, R. D., Scharz, D. W. F., & Landolt, J. P. (1987). **Vestibular nuclear neuron activity during active and passive head movement in the alert rhesus monkey.** *J. Neurophysiol., 57,* 1484-1497.

Abstract Responses of single neurons were recorded in the medial and descending vestibular nuclei (MVN and DVN) and in the deep cerebellar nuclei of three juvenile rhesus monkeys (*Macaca mulatto*). Neuronal activity was measured during both passive sinusoidal and nonsinusoidal whole body rotation (peak velocities were under 90°/s) and during active head movements. Although the active head movements occasionally exceeded 300°/s, most exhibited peak velocities of <200°/s.

A total of 133 units sensitive to horizontal head rotation were recorded, and of these, 38 were held for sufficient time to obtain both passive and active head movement data. Comparison of the neuronal firing patterns obtained during active and passive head movements revealed no apparent differences. Thus neurons that were observed to burst or pause during saccades with the head fixed continued to do so when the head was free.

Both the sensitivity to head velocity and the "inferred" spontaneous firing rate were compared during active and passive head movements by plotting rate-velocity curves for both conditions. When the data points were fitted with linear regression lines, no statistically significant differences in either sensitivity or spontaneous rate were found.

The present study provides no evidence that efferent vestibular activity alters the properties of afferent vestibular neurons during active head movements, as has previously been suggested. Furthermore, neurons in the rostral portions of the vestibular nuclei in primates encode head velocity based entirely on labyrinthine information. Neither neck proprioceptors nor an efference copy of the head movement motor program seem to contribute significantly to the firing patterns observed.

Knowles, D., Buick, F., Robbins, G., Kuhlman, W., & Weiss, R. (1987). **Physiological implications of wearing CCBA for NBC protection.** In *International Task Force-3.Report No. ITF-3.* (pp. 210-218). US/UK/CAN MOU on CB Defence. (Restricted).

Abstract (Restricted Report)

Martineau, L., & Larochelle, J. (1987). **The cooling power of pigeon legs.** *J. exp. Biol., 136,* 193-208.

Abstract The rate of heat loss from legs and feet (H_{LEG}) was studied in resting pigeons preheated to a body temperature (43.1°C) close to those recorded during flight.

The experimental system was designed to allow the calculation of H_{LEG} from whole-body cooling rates following exposure of the leg and feet to various combinations of wind speed (0–75 $km.hr^{-1}$) and air temperature (5–25°C). The pigeons remained hyperthermic when their hind limbs were kept insulated, but their bodies cooled markedly as a result of exposure of the legs and feet. With a 12.5 $km.hr^{-1}$ wind at 25°C,H_{LEG} corresponded to 240% of the resting heat production. H_{LEG} was increased by higher wind speed and lower air temperature, but it became essentially independent of wind speed above 37.5 $km.hr^{-1}$. The maximum values of H_{LEG} were 4–6 times as large as the resting heat production and could account for 50–65% of the total heat produced during flight. It is concluded that in a non-aquatic bird the legs and feet can play a major role in whole-body thermoregulation, both at rest and during flight.

Money, K. E., Cheung, B. S., & Kirienko, N. M. (1987). **An Illusion of reversed direction in hyperopes.** *Perceptual and Motor Skills., 65,* 615-618.

Abstract If a subject who is sufficiently farsighted removes his corrective, positive, lenses and looks with one eye from a distance of one or a few meters, at a small lighted area such as the (continuously "on") indicator light of an electric toothbrush, razor, or smoke detector, and if a small object such as a pin is then moved slowly from above to below the subject's eyes (in a plane close to the eye), the subject will perceive the object moving normally from above to below until it encroaches on his view of the lighted area. The object will then be seen to encroach first on the *bottom* of the lighted area, and as the object continues to move down it will be seen to be moving *up* across the lighted area, exiting the lighted area at the top. Similarly, an object moved in front of the eye from the subject's left to his right will be seen by the subject to traverse the lighted area in the reverse direction, right to left, even though the subject moves the object himself. Also, while the object is in front of the lighted area, it is perceived as an upside down silhouette having surprisingly clear and sharp edges, and it appears to be located *on* the lighted area rather than close to the eye where it really is.

Ohmi, M., Howard, I. P., & Landolt, J. P. (1987). **Circular vection as a function of foreground-background relationships.** *Perception, 16,* 17-22.

Abstract It has previously been reported that illusory self-rotation (circular vection) is most effectively induced by the more distant of two moving displays. Experiments are reported in which the relative effectiveness of two superimposed displays in generating circular vection as a function of (i) the separation in depth between them, (ii) their perceived relative distances, and (iii) which display was in the plane of focus was investigated. Circular vection was governed by the motion of the display that was perceived to be the more distant, even when it was actually nearer. However, actual or perceived distance was found to be not the crucial factor in circular vection because even when the distance between the two displays was virtually zero, vection was controlled by the display perceived to be in the background. When the displays were well separated in depth, vection was not affected by whether the near or the far display was in the plane of focus, nor by which display was fixed or pursued by the eyes.

Ward, C. A., McCullough, D., & Fraser, W. D. (1987). **Relation between complement activation and susceptibility to decompression sickness.** *J. Appl. Physiol., 62*(3), 1160-1166.

Abstract The consequences of complement activation and the symptoms of decompression sickness are similar. Consequently, the relation between the sensitivity of individuals to complement activation by air bubbles and their susceptibility to decompression sickness has been examined. Plasma samples from 34 individuals were incubated with air bubbles, and the concentration of the fluid phase metabolites of complement activation C3a, C4a, and C5a were measured with radioimmunoassays. It was found that both the anaphylatoxins C3a and C5a were produced by the presence of air bubbles but that the anaphylatoxin C4a was not. This finding indicates that air bubbles activate the complement system by the alternate pathway. One group of individuals was found to be particularly sensitive to complement activation by this pathway. They produced 3.3 times more C3a and 5.3 times more C5a in their plasma samples incubated with air bubbles as did the other group. Sixteen individuals were subjected to a series of pressure profiles that were severe enough to produce bubbles in their circulatory system that could be detected by Doppler ultrasonic monitoring. The group of individuals that had been identified as being more sensitive to complement activation by the alternate pathway was also found to be more susceptible to decompression sickness.

Ward, C. W., McCullough, D., & Fraser, W. D. (1987). **Identification of individuals susceptible to decompression sickness.** In A. A. Bove, A. J. Bachrach, & J. L. G. Greenbaum (Ed.), *9th International Symposium on Underwater and Hyperbaric Physiology,* (pp. 239-248). Undersea and Hyperbaric Medical Society.

Abstract Previous theories that have been advanced to predict the occurrence of decompression sickness (DCS) have been developed assuming that all individuals are physiologically the same. Complement sensitivity, maximum likelihood metrics, and Doppler bubble scores are compared for their ability to account for the variability in individual DCS susceptibility in a test population of 15 subjects. Subjects classified as complement sensitive had a 50% occurrence of decompression sickness, an average bubble grade of 2.8 and a maximum likelihood score of 0.504. Subjects classified as complement insensitive had no decompression sickness, a bubble score of 3.1 and a maximum likelihood score of 1.014. Both bubble grades and maximum likelihood score would indicate a greater likelihood of decompression sickness in the insensitive group. The complement sensitive group were however more susceptible to decompression sickness ($P < 0.05$). For decompression sickness to occur bubbles must be present and the complement enzyme must be sensitive to activation.

1988

Buick, F., Maloan, J., Grottenthaler, J., & Bogart, R. (1988). ***Physiological responses during graded intensity walking with closed-circuit breathing apparatus.*** (DCIEM 88-RR-36 (Confidential)). Defence and Civil Institute of Environmental Medicine.

Abstract (Confidential Report)

Fowler, B., Kelso, B., Landolt, J., & Porlier, G. (1988). **The effects of nitrous oxide on P3300 and reaction time.** *Electroenceph. Clin. Neurophysiol., 69,* 171-178.

Abstract The experiment investigated the effects of 3 concentrations (15%, 25% and 35%) of nitrous oxide (N_20) on reaction time (RT) and P300 latency and amplitude. Ten subjects responded to visually presented male or female names in an oddball paradigm with accuracy controlled at a high level. The results were analysed on a single-trial basis. Nitrous oxide increased both RT and P300 latency in a dose-related manner and

these variables showed a strong between-dose correlation (r = 0.67). Nitrous oxide also decreased P300 amplitude but only up to the 25% dose. The between-dose correlation for P300 amplitude and RT was negligible (r = –0.14). These results suggest that P300 latency is an index of N_20 narcosis and are interpreted as indicating that narcosis involves the slowing of stimulus evaluation processes.

Goodman, L., McKenzie, D. C., & Taunton, J. E., Walters, M.B. (1988). **Relationship between ventilatory threshold and training heart rate in exercising cardiac patients.** *Can. J. Sport. Sci., 13*(4), 220-224.

Abstract The purpose of this study was to determine the relationship between previously prescribed training heart rates (THR) for patients training for six months or more in a cardiac rehabilitation program (CRP), calculated Karvonen percentage heart rate reserve (THR_k), and the ventilatory threshold (VT). In twenty male patients (ages 41-63) with documented coronary heart disease (CAD) [non-medicated] mean training heart rate (TRH. 75% HRmax) was determined by a telemetry during training sessions. Incremental treadmill testing for determinations of the gas-exchange VT $\dot{V}O_2$ vs. ($\dot{V}O_2$, Excess CO_2) was performed, and the HR at the VT (VTHR) was determined. $\dot{V}O_2$max was 35.57 ± 5.57 $mL \cdot kg^{-1} \cdot min^{-1}$; the VT, expressed as a percentage of $\dot{V}O_2$max, was 54.45%. The mean THR (133.8 ± 13.4 bpm) and calculated THR_k (141.1 ± 9.74 bpm) were significantly greater ($p < .05$) than the VTHR (124.8 ± 15.5 bpm) indicating that VT occurs below intensities determined by other methods.

Reinis, S., Weiss, D. S., & Landolt, J. P. (1988). **Lack of homogeneity of receptive fields of visual neurons in the cortical area 18 of the cat.** *Biol. Cybern., 59,* 41-48.

Abstract The receptive fields of "complex" neurons within area 18 of the cerebral cortex of the cat were determined by a computer-assisted method using a moving light bar substantially shorter than the long diameter of the receptive field as a visual stimulus. The visual cells repeatedly generated nerve impulses when the stimulus crossed well-defined "active points" within their receptive fields. Outside of these active points, the cells remained silent. It is suggested that the receptive fields are formed by a discontinuous accumulation of such active points. When the electrical activities of two neighbouring visual neurons are recorded simultaneously, their active points do not coincide. In addition, some active points were located outside the most prominent excitatory part of the receptive field of the studied cells. Individual visual cells typically differ in the number and distribution of active points. Since these cells best respond to a stimulus moving in a certain direction, it is suggested that they may act as direction of movement and/or velocity detectors. Alternate firing of a number of neighboring cells connected to a distributed pattern of peripheral receptors may form a system which is able to code for velocity and direction of the moving stimulus.

Reinis, S., Weiss, D. S., & Landolt, J. P. (1988). **Mass correlograms of multiple neuronal activity in the cat's extrastriate cortex.** *Biol. Cybern., 59,* 103-107.

Abstract Electrical activity of a population of visually responsive cells located in the vicinity of a single functionally defined neuron was recorded in the area 18 of the cat's cerebral cortex with a single tungsten microelectrode. The correlograms calculated from the mass activity record showed an ex-

istence of a rhythmic neuronal firing with an average interval near to 3 ms. When the system was activated by a visual stimulus, a line at an optimal angle moving in an optimal direction, the rhythmic activity became regular, acquiring an oscillatory sinusoidal character. This rhythmic pattern cannot be easily recognized when the activity of a single neuron is recorded. It is possible that such rhythmic activity involving large numbers of neuron contributes to the recognition of the velocity an position of the visual stimulus.

1989

Ackles, K. N., & Radomski, M. W. (1989). **High(er)-flying Phoenix.** In *FORUM*, 4, (pp. 33-35).

Abstract Project Phoenix developed improved emergency aircrew protection against altitudes greater than 60,000 ft. It explored the physiological response of humans to very high levels of positive pressure breathing (PPB) and showed that inflating the G-suit to 4 times the level of PPB provided much improved protection. This concept was further developed as the Tactical Life
Support System (TLSS) in a cooperative program with the USAF.

Buick, F. (1989). ***+Gz Protection in the Future - Review of Scientific Literature.*** (DCIEM 89-RR-47). Defence and Civil Institute of Environmental Medicine.

Abstract To reduce the incidence of G-induced loss of consciousness and enable pilots to operate their aircraft at higher levels of performance, anti-G protection must be improved. A G-suit and the anti-G straining maneuver will likely remain essential components of any anti-G system, but several methods potentially increasing G-tolerance have been investigated that could supplement the protection afforded by these traditional techniques. Pharmacologic agents are of no benefit, while breathing carbon dioxide, shown to improve G tolerance, is impractical. Positive pressure breathing has so convincingly improved G-protection that it will become an operational procedure in the immediate future. The benefits of the G-suit have been augmented through greater coverage of the lower body and efforts are also aimed at more responsive G-valves. Altering body position to shorten the heart-to-head hydrostatic distance adds directly to the protection offered by the other procedures but can impair vision and must wait until the cockpit is redesigned.

Cheung, B. S. K., Howard, I. P., Nedzelski, J. M., & Landolt, J. P. (1989). **Circularvection about earth-horizontal axes in bilateral labyrinthine-defective subjects.** *Acta Otolaryngol (Stockh), 108,* 336-344.

Abstract A stationary subject surrounded by a visual display rotating about an earth-horizontal axis typically experiences a sensation of continuous self-rotation (vection) coupled with a paradoxical sensation of a limited degree of body tilt, both opposite to the direction of the stimulus. The sensation of limited body tilt has been attributed to conflict between visually-induced vection, and otolithic and somatosensory graviceptive information which indicates that the body has not moved. We investigated circularvection and illusory body tilt about the horizontal axis in the pitch and roll planes in bilateral labyrinthine-defective (L-D) subjects. Results demonstrated that the bilateral group experienced complete unambiguous self-rotation through an upside-down orientation. The relative contributions of the otolithic and somatosensory graviceptors to visual-induced tilt is discussed.

Fowler, B., Mitchell, I., Bhatia, M., & Porlier, G. (1989). **Narcosis has additive rather than interactive effects on discrimination reaction time.** *Human Factors, 31,* 100-108.

Abstract A central feature of the impairment in performance produced by inert gas narcosis, which poses a threat to divers breathing compressed air, is a slowing of reaction time (RT). To investigate the locus of this slowing, the effects of 35% nitrous oxide on Crossman's confusion function were determined using line-length and weight discrimination tasks, with accuracy held constant. For both tasks narcosis slowed RT by increasing the intercept rather than the slope of Crossman's function. These results are interpreted in terms of additive factors method logic as being consistent with the predictions of the slowed processing model that has been proposed to account for the effects of narcosis on human performance.

Fraser, W. D. (1989). **Blood complement analysis and decompression sickness.** In *Proceedings of the Fifth Scientific Diving Symposium: Diving for Science,* Toronto, Ontario: Canadian Association for Underwater Science.

Abstract The complement enzyme system of blood plasma is one of the components of the body's system. Work performed over the last several years has shown that much of the phenomena of decompression sickness (DCS) are due to activation of this immune response by gas babbles. It has been found that those divers that develop symptoms of DCS are also found to have native complement systems that are readily activated by air bubbles. Those divers that do not show symptoms have complement systems that are not sensitive to activation by air bubbles. It has also been shown that activation of the complement enzyme system by gas bubbles is a primary factor in the agglutination of white blood cells and platelet activation. Both these processes are believed to be critical factors in the development of DCS. Additional support for the importance of the complement enzyme system in the development of DCS was obtained from another study in which rabbits were exposed to decompression profiles sufficient to induce DCS. Rabbits showing symptoms of DCS when initially exposed to decompression stress could be protected during subsequent exposures by pharmacologically suppressing the complement system prior to the decompression stress.

Fraser, W. D., & Baines, A. D. (1989). **Application of fiber-matrix model to transport in renal tubules.** *J. Gen. Physiol, 94,* 863-879.

Abstract The effects of tight junction structure on water and solute fluxes across proximal tubular epithelium were examined with fiber-matrix equations previously derived by Curry and Michel (1980. *Microvascular Research.* 20:96-99). Using plausible estimates of tight junction fiber length and width the model predicts solute (P_s) and water permeability (L_p) coefficients that agree with the measured values. When fiber-matrix and pore models were compared for physiologically relevant ranges of matrix void fraction (80-98%) and pore radii (0-20 A), the fiber-matrix model predicted a 10-fold higher L_p/P_s ratio. L_p/P_s was most sensitive to small changes in tight junction structure when void fractions exceeded 90%. Void fractions of 96.5% and 97.1% predicted previously measured values for L_p/P_s and solute permeabilities in rat and rabbit proximal tubules. These values are consistent with void fractions and permeabilities of artificial membranes. The fiber-matrix tight junction model was incorporated into a model of reabsorption from the rat proximal tubule developed by Weinstein (1984. *American Joumal of Physiology.* 247:F848-F862.) A void fraction of 98% predicted the experimental results for isoso-

motic reabsorption driven by active transport. Changing void fraction over the range of 97-99% produced a 50-75% change in predicted volume reabsorption with active transport. According to the fiber-matrix model: (a) solute permeabilities alone cannot be used to predict L_p, (b) previously measured solute permeabilities in the proximal tubule are compatible with significant water reabsorption through a water-permeable tight junction, and (c) hydraulic and solute permeabilities may be sensitive to small changes in tight junction fiber length and diameter or ionic strength within the tight junction.

Hamilton, K., Fowler, B., Landolt, J., & Porlier, G. (1989). **Nitrogen narcosis and ethyl alcohol increase the gain of the vestibular ocular reflex.** *Undersea Biomed. Res., 16*(2), 129-137.

Abstract The effects of air, helium-oxygen (6.4 ATA) and ethyl alcohol (40% by volume at a dose of 1.5 ml/kg body weight) were examined on the gain, number of beats, and phase lag of the vestibular ocular reflex (VOR) by means of electronystagmography (n = 7). It was found that hyperbaric air and alcohol, both alone and in combination, produced approximately the same increase in the velocity of the slow phase component of the nystagmus, thereby elevating the gain of the system to unity. Hyperbaric helium-oxygen did not influence the gain. These findings suggest that nitrogen narcosis differentially impairs the system controlling the VOR. It is proposed that this impairment may help to explain the disorientation sometimes associated with nitrogen narcosis.

Hamilton, K., Fowler, B., & Porlier, G. (1989). **The effects of hyperbaric air in combination with ethyl alcohol and dextroamphetamine on serial choice-reaction time.** *Ergonomics, 32*(4), 409-422.

Abstract The effects of ethyl alcohol (1.5 ml/kg body weight) and dextroamphetamine (15 mg) on nitrogen narcosis were investigated In two experiments using a 2-, 3- and 4-choice serial reaction time (RT) task with accuracy held constant. Narcosis was induced with air at 6.4 atmospheres absolute (ATA) and a heliox mixture was used as a control. Heliox at 6.4 ATA did not affect RT. Alcohol alone and air at 6.4 ATA increased the intercept of the Hick-Hyman function whereas amphetamine alone decreased it. The increased intercept with air at 6.4 ATA was exacerbated additively by alcohol and ameliorated antagonistically by amphetamine. It is concluded that these data are consistent with the slowed processing model which proposes that the effects of narcosis on performance are due to a decrease in arousal in conjunction with secondary changes in task strategy.

Landolt, J. P., & Monaco, C. (1989). ***Seasickness in occupants of totally-enclosed motor-propelled survival craft (TEMPSC).*** (DCIEM Report #89-RR-14). Defence and Civil Institute of Environmental Medicine.

Abstract Seasickness is universally acknowledged to be a most unpleasant experience, and, in its extreme form, leaves the victim unwilling even to assist in his/her own rescue. In 1984, following a rescue off Sable Island, Nova Scotia from a totally-enclosed motor-propelled survival craft (TEMPSC) carrying personnel from the abandoned oil rig, Vinland, one 31-year-old man subsequently died. All aboard the TEMPSC were extremely seasick, and it has been suggested that this was a contributing factor in the man's death. This incident precipitated debate concerning the necessity of recovering evacuees from a TEMPSC as soon as possible. On the one hand, it was argued, resources should be committed to developing techniques to recover TEMPSC occupants as an alternative to prolonged lifeboat confinement.

On the other hand, it was argued that any transfer technique at sea is risky, and having safely evacuated a drilling unit, evacuees should be left in the TEMPSC until sea conditions are sufficiently moderate to ensure safe recovery of personnel by conventional means. Resolution of the debate (aside from other factors) appeared to be the comparison of the risk involved in undertaking a transfer at sea under adverse conditions against the risk of prolonged exposure to rough seas while in the TEMPSC.

Ward, C. A., McCullough, D., Yee, D., & Fraser, W. D. (1989). **The role of complement activation in decompression sickness.** In Y. Lin & K. K. Shida (Ed.), *Proceeding of the 2nd International Symposium on "Man in the Sea"*, (pp. 253-271). Hawaii: University of Hawaii.

Abstract Complement activation by air bubbles appears to play a mediating role in decompression sickness (DCS). If an individual's native complement system is sensitive to activation by air bubbles, then he/she is susceptible to DCS. Individuals whose complement systems are not activated by air bubbles are found to be immune to DCS on the pressure profiles to which we have subjected them. The known genetic polymorphism of the molecules that initiates activation of the complement system along the alternative pathway provides a possible explanation for the variation in the sensitivity of individuals to complement activation by air bubbles and thus to their variation in susceptibility to DCS. Acclimatization is hypothesized to arise when individuals become effectively decomplemented by circulatory bubbles produced when they undergo a repetitive series of pressure profiles. The hypothesis is supported by observations with rabbits. It is found that rabbits can be "Acclimatized" by pharmacologically decomplementing them and that decomplemented rabbits become "De-acclimatized" when they are allowed to rest for a period that is sufficient for their complement system to return to its native sensitivity.

Watt, D. G. D., & Landolt, J. P. (1989). **Effects of short-term weightlessness on roll circularvection.** In *Situational Awareness in Aerospace Operations*, AGARD-CP-478, (pp. 20-1 - 20-6). AGARD, Paris, France.

Abstract Roll circularvection is an illusion of self-rotation about the fore-aft axis experienced when a stationary subject is exposed to a visual field rotating in the frontal plane. In these experiments, subjects have been asked to estimate the strength of this phenomenon while undergoing visual stimulation in the upright and supine positions, and during parabolic aircraft flight. The results indicate that the steady roll component of vection is not affected by the magnitude or direction of the gravity vector. The unpredictable and sudden loss of this compelling illusion could contribute to serious episodes of pilot disorientation.

Wolfe, L. A., Hall, P., Webb, K. A., Goodman, L., Monga, M., & McGrath, M. J. (1989). **Prescription of aerobic exercise during pregnancy.** *Sports Medicine, 8*(5), 273-301.

Abstract Available evidence supports the existence of both risks and benefits of aerobic conditioning during human pregnancy. During intensive exertion, material skeletal muscle and fetus may compete for blood flow, oxygen delivery and essential fuel substrates. Hence, the most important hypothetical risks include acute fetal hypoxia, hyperthermia and malnutrition. If exercise is repeated on a chronic basis, teratogenic effects, fetal growth retardation or altered fetal development may result if maternal/fetal adaptive reserve is exceeded. A dose-response relationship for such effects has been demonstrated in laboratory animals, but specific findings may have limited

applicability to voluntary exercise in pregnant women.

Although further investigation is needed, the majority of published studies suggest that fitness-type conditioning does not jeopardize fetal well-being in health well-nourished women. Benefits of such exercise appear to include increases in maximal aerobic power ($\dot{V}O_2max$ L/min) and enhanced cardiopulmonary reserve. It has also been proposed that exercise prevents accumulation of excess body fat, promotes psychological well-being, helps to prevent gestational diabetes and low back pain and may facilitate labour. However, these benefits remain to be confirmed by objective scientific study.

Due primarily to a lack of scientific data, existing medical guidelines for exercise during pregnancy are conservative and follow a common sense approach. Good agreement exists on the need for pre-participation medical screening and continuing surveillance to verify the existence of material/fetal adaptive reserve. Woman are advised to select safe, non-ballistic exercise modualities and to avoid thermal or hyperbaric environmental stress during exercise. Exercise in the supine position is also prudent to avoid, particularly in the gestation. The usefulness of heart rate in prescribing and monitoring exercise intensity has been questioned, with use of conventional perception of exertion scales being the most logical alternative. Prediction of maximal aerobic power ($\dot{V}O_2max$) from submaximal work rate/heart rate relationships is also problematic during pregnancy. Other areas of debate include the advisability of initiating a new exercise programme during pregnancy, methods for prevention of fetal hyperthermia, the safety of weight-training/isometric exercise and optimal methods for training of pre/postnatal fitness instructors.

1990

Buick, F., Burton, R. R., Clère, J. M., Glaister, D. H., Hoekstra, G. J. T., Johansen, T. S., Maat, G. K. M., & Meeker, L. (1990). ***High +Gz Physiological Protection Training.*** Paris, France: Aero-Medical Panel WG 14, Advisory Group for Aerospace Research and Development, NATO AGARDograph No. 322.

Abstract High-G physiological protection training is currently of importance to NATO Air Force operations because of a deficiency in G protection methods. This deficiency can, and on occasion does, result in G-induced loss of consciousness (G-LOG) (Chapter 1). Consequently, these methods are supported and supplemented by increasing their effectiveness through: (a) increased understanding of the physiologic basis of G protection (Chapters 2 and 3); (b) development of advanced G protection concepts (Chapter 4); (c) knowledge of the system and basis of G-LOC (Chapter 5); (d) identification of the existence and location of human use centrifuges in NATO countries (Chapter 6); (e) increased physical conditioning (Chapter 7); (f) improved training of pilots on the centrifuge (Chapter 8); and (g) establishment of training goals and standards (Chapter 9). These topics are addressed at a scientific or technical level of knowledge that is possessed by everyone involved in acceleration research, G training, flying, or designing and building high performance aircraft. At the end of each chapter is a brief summary in both English and French.

The material in this publication was assembled to report the results of AGARD Aerospace Medical Panel Working Group 14.

Cheung, B., Money, K., & Jacobs, I. (1990). **Motion sickness susceptibility and aerobic fitness: a longitudinal study.** *Aviat. Space Environ. Med., 61,* 201-204.

Abstract A longitudinal study evaluated the susceptibility to motion sickness in initially unfit subjects before and after an endurance training program. Motion stimulation was provided by the Precision Angular Mover, in which the subject was tumbled head over heels about an Earth-horizontal axis at 20 cycles per minute in darkness. Maximal aerobic power and the blood lactate response to submaximal exercise were evaluated with cycle ergometry. The training program caused significant improvements in $\dot{V}O_2$ max and endurance capacity, and a significant decrease in percent body fat. There was a significant ($p < 0.0125$) increase in motion sickness susceptibility after the physical training, suggesting that increased physical fitness caused increased susceptibility to motion sickness in some individuals.

Cheung, B. S. K., Howard, I. P., & Money, K. E. (1990). **Visually induced tilt during parabolic flights.** *Exp Brain Res, 81,* 391-397.

Abstract A helmet-mounted visual display system was used to study visually induced sensations of self-motion (vection) about the roll, pitch and yaw axes under normal gravity condition (1g) and during the microgravity and hypergravity phases of parabolic flights aboard the NASA KC-135 aircraft. Under each gravity condition, the following parameters were investigated: (1) the subject's perceived body vertical with eyes closed and with eyes open gazing at a stationary random dot display; (2) the magnitude of sensations of body tilt with respect to the subjective vertical, while the subject viewed displays rotating about the roll, pitch and yaw axes; (3) the magnitude of vection; (4) latency of vection. All eleven subjects perceived a definite "up and down" orientation throughout the course of the flight. During the microgravity phase, the average magnitudes of perceived body tilt and self-motion increased significantly, and there was no significant difference in vection latency. These results show that there is a rapid onset of increased dependence on visual inputs for perception of self-orientation and self-motion in weightlessness, and a decreased dependence on otolithic and somatosensory graviceptive information. Anti-motion sickness drugs appear not to affect the parameters measured.

Fowler, B., Pogue, J., & Porlier, G. (1990). **P300 latency indexes nitrogen narcosis.** *Electroencephalography and Clinical Neurophysiology, 75,* 221-229.

Abstract This experiment investigated the effects of nitrogen narcosis on reaction time (RT) and P300 latency and amplitude. Ten subjects breathed either air or a non-narcotic 20% oxygen-80% helium (heliox) mixture in a hyperbaric chamber in 6.5, 8.3 and 10 atmospheres absolute (ATA). The subjects responded under controlled accuracy conditions to visually presented male or female names in an oddball paradigm. Single-trial analysis revealed a strong relationship between RT and P300 latency, both of which were slowed in a dose-related manner by hyperbaric air but not by heliox. A clear-cut dose-response relationship could not be established for P300 amplitude. These results indicate that P300 latency indexes nitrogen narcosis and are interpreted as support for the slowed processing model of inert gas narcosis.

Ward, C. A., McCullough, D., Yee, D., Stanga, D., & Fraser, W. D. (1990). **Complement activation involvement in decompression sickness of rabbits.** *Undersea. Biomed. Res., 17*(1), 51-66.

Abstract A hypothesis has been proposed that claims much of the phenomena of decompression sickness (DCS) are mediated by the complement system of blood plasma. This "complement hypothesis" can be used to explain the variation in susceptibility of in-

dividuals to DCS, including the phenomena of acclimatization and de-acclimatization. In this study, certain predictions of the complement hypothesis were examined by exposing rabbits to a particular pressure profile; some were observed to have symptoms of DCS and some showed none. Those that were observed to have symptoms were also found to have native complement systems that were activated by air bubbles, and those that did not show symptoms of DCS when exposed to the same pressure profile had native complement systems that were not activated by air bubbles. Rabbits that had shown symptoms of DCS the first 2 times that they were exposed to the pressure profile could be acclimatized to the pressure profile by pharmacologically decomplementing them in vivo. After being decomplemented, they showed no symptoms of DCS when they were exposed to the same pressure profile for a third time. When the decomplemented rabbits were allowed to remain inactive for a period of time that was sufficient to allow their complement systems to return to normal, after having been decomplemented, and were then subjected to the pressure profile for the fourth time, they were each again observed to have symptoms of DCS, i.e., they became de-acclimatized when their complement systems had returned to their native sensitivity. These results provide further experimental support for the complement hypothesis.

Wolfe, L. A., Dafoe, W. A., Hendren-Roberge, E. A., & Goodman, L. S. (1990). **Cardiovascular rehabilitation in Ontario (Canada).** *J. Cardiopul. Rehabil., 10,* 130-140.

Abstract Hospitals, YM-YWCAS, regional health units, and university physical education and athletics departments (n = 423) were surveyed to determine the number and locations of existing cardiovascular rehabilitation units (CRUs). A total of 43 CRUs were identified by these inquiries and 135 additional institutions expressed interest in future establishment of a CRU. Hospitals and medical clinics (n = 25) were the most common sponsoring institutions for CRUs, followed by YM-YWCAs (n = 10), community organizations (n = 5) and university physical education/kinesiology departments (n = 3). Contact persons at 37 of the 43 existing CRUs subsequently completed and returned written questionnaires which described their unit's status and operating procedures. The replies suggested the following conclusions: (1) an outpatient (OP) exercise program was the most commonly offered program component; (2) nutritional counseling, stress management, smoking cessation programs, and exercise programs for inpatients were also frequently offered; (3) the majority of patients treated were post-myocardial infarction and post-cardiac surgery patients, with lesser numbers of angina and coronary-prone patients; (4) adequate facilities and equipment were usually available; (5) considerable variability existed regarding qualifications of staff and methods for enhancing staff education; (6) respondents were often unfamiliar with the CASS/ACSM Exercise Specialist Certification program, and few certified individuals were employed; and (7) health insurance and professional liability insurance coverage were often inadequate, suggesting an urgent need for development of a Canadian procedural guidelines and better communication among practitioners in this field.

1991

Buick, F., & Porlier, J. A. G. (1991). **Oxyhemoglobin saturation following rapid decompression to 18,288 m (60,000 ft) preceded by diluted oxygen breathing.** *Aviat. Space Environ. Med., 62,* 1119-1126.

Abstract This investigation studied oxyhemoglobin saturation SaO2 and cardiovascular indices after rapid decompression (RD). Before RD, fractional inspired O2 con-

centration FIO2 simulated the range of product gas from molecular sieve O2 generating systems (MSOGS). Four subjects breathed 1.0 - 0.80 FIO2 at 6,858 m. After decompression to 18,288 m, the subjects received 1.0 FIO2 at a positive pressure of 70 mm Hg for 3 min. There were no incidents of severe hypoxia. The mean SaO2 was 98.0% before RD. After RD, SaO2 was maintained at the pre-RD level for 8 sec, decreased rapidly over the next 10 sec, and over the rest of the first min decreased more gradually to reach approximately 82%. Varying FIO2 before RD had no effect on the alteration in SaO2, heart rate, stroke index, and blood pressure after RD. The MSOGS O2 product range offers adequate protection against hypoxia during RD to 18,288 m.

Campbell, P., Cheng, R., & Fraser, W. D. (1991). **Physiological response induced by the environment model (PRIEM).** In K. D. Held, C. A. Brebbia, & R. D. Ciskowski (Eds.), *Computers in Biomedicine.* (pp. 23-33). Southampton: Computational Mechanics Publications.

Abstract The purpose of this project is to design and develop a computer program to simulate the respiratory, cardiovascular, and certain cerebral responses of pilots subjected to stresses imposed by the operating environment of high performance aircraft The project work consists of four Phases. Phases I and 2 are completed. The Phase 2 implementation simulates blood circulation, pulmonary gas exchange, and internal respiration using a cardiorespiratory model developed by Hardy *et al.*, LabVIEW and think C software on a Macintosh Ilci computer.

Cheung, B. S. K., & Howard, I. P. (1991). **Optokinetic torsion: dynamics and relation to circularvection.** *Vision Research, 31*(7-8), 1327-1335.

Abstract Continuous records of optokinetic torsion to sinusoidal inputs were obtained using the electromagnetic scleral search-coil technique. We measured the gain and phase lag of optokinetic torsion in response to a spherical visual display rotating steadily at various angular velocities and sinusoidally at frequencies from 0.2 to 2.0 Hz and at amplitudes from 10 to 80 deg. Gain (peak slow-phase eye velocity over stimulus angular velocity) of up to 0.12 were obtained with stimulus frequencies of 0.2 Hz and declined to an average value of about 0.02 at a frequency of 2.0 Hz. Phase lag was virtually zero at a frequency of 0.2 Hz and increased to over 80 deg at 2.0 Hz. The records from the sinusoidal stimuli show very few quick phases. With increasing stimulus amplitudes, the amplitude of the response increased by its gain declined. We found no evidence of torsional after-nystagmus nor any relation between the torsional response and reports of vection or sensation of body tilt induced by the rotating display. Torisional optokinetic nystagmus is most suited to compensate for low-amplitude, low-frequency stimulus rotation and normally supplements torsion induced by head tilt.

Cheung, B. S. K., Howard, I. P., & Money, K. E. (1991). **Visually-induced sickness in normal and bilateral labyrinthine-defective subjects.** *Aviat. Space and Environm Med, 62,* 527-531.

Abstract A group of nine normal subjects (with no overt vestibular dysfunction) and a group of 6 bilaterally labyrinthine-defective subjects were exposed to a visual field rotating about an Earth-horizontal axis (orthogonal to the gravity axis). The visual stimulus was provided by a 3-m diameter sphere with random dots rotating at 30, 45, and 60 degrees per second (°/s) about the stationary subject's roll, pitch and yaw axes. The subject's head was positioned at the center of the sphere such that it experienced

apparent motion in all three axes. Results indicated that in the normal group, symptoms of motion sickness were reported in 21 of 27 test-trials. When labyrinthine-defective subjects were exposed to the roll and pitch stimulus, no sickness symptoms were reported or observed. These results strongly suggest that the vestibular system is necessary for sickness induced by moving visual fields.

Davidson, R. A., Beevis, D., Buick, F., Donati, A. L. M., Kantor, L., Bannister, S. H. R., Brook, E. A., Rochefort, J. A. P., & Turner, J. R. (1991). ***Human factors in the CF-18 pilot environment.*** (DCIEM 91-11). Defence and Civil Institute of Environmental Medicine.

Abstract A review of human factors in the CF-18 pilot environment was undertaken. Over 300 human factors issues were initially identified from the scientific literature, the 1 Air Division and Fighter Group safety surveys, and discussions with military and civilian flight safety/human factors experts. Eighty-eight (88) of the issues most relevant to CF-18 operations were selected and grouped under five functional, or "Factor," headings: Aircraft, Aircraft Operations, Training, Squadron Personnel, and Organizational. Issues were evaluated using a questionnaire and interview format.

One hundred and sixty-one (161) active CF-18 pilots took part in the survey. They were asked to assess, from a squadron perspective, the current effect of each issue on two parameters: flight safety and operational effectiveness. Each issue was rated on a scale ranging from very beneficial to very detrimental. Ratings were analyzed using the non-parametric procedure of dual scaling.

Issues within the Aircraft and Aircraft Operations groups were divided almost equally between the beneficial and neutral categories. Most of the Training Factor issues were rated as beneficial. Among the issues within the Squadron Personnel Factor, comparable numbers received beneficial, neutral and detrimental ratings. One-quarter of the issues within the Organizational group were rated as detrimental, with most of the remainder rated as neutral. In general, issues beneficial to flight safety were also beneficial to operational effectiveness. Similarly, issues rated as detrimental to flight safety were also rated as detrimental to operational effectiveness.

Cause and effect models were developed to explain the ratings. These models support the opinion that the greatest threats to flight safety and operational effectiveness are the decreasing level of flying experience in the squadrons, and inadequate manning levels.

Twenty-eight (28) specific conclusions are made, in the areas of the human-machine system, aircraft operations, training, personnel and organizational policies, and workload in the squadrons. Twenty-five (25) specific recommendations for improving flight safety and operational effectiveness are presented in the areas of organizational policies, training programmes, and the human-machine system.

Landolt, J. P. (1991). **La protection des pilotes militaires contre les effets de la haute altitude et des accélerations élevées.** *Médecine Aéronautique et Spatiale, XXX*(120), 482-485.

Abstract The papers presented at the Spring 1991 AGARD/AMP Symposium on "High Altitude and High Acceleration Protection of Military Aircrew" emphasized the importance of sound basic knowledge in understanding the pathophysiology of decompression sickness and the consequences of high accelerations in high performance aircraft military pilots.

The use of mathematical and animal models provides a new approach of the mechanisms of ebullism and tissue damage during decompression; especially as it relates to the nervous system.
When applied to the assessment of the consequences of high acceleration (i.e. over > 6

Gz) on circulatory and respiratory systems, this knowledge will enable a reduction in the incidence of G-LOC, more efficient anti-G straining manoeuvres, and, consequently, an increased pilot tolerance to Gz.

The current wearing of anti-G garments including ATAGS and COMBAT EDGE, the US Air Force's new positive pressure breathing system, also requires a better understanding of the short and long term effect of positive pressure breathing in combination with high acceleration on lung function. This will result in new designs and in an increase in reliability and safety of on-board oxygen generation systems, for better tolerance and greater protection of military aircrew for these specific hazards.

McKenzie, D. C., Goodman, L. S., Nath, C., Davidson, B., Matheson, G., Parkhouse, W., Hochochka, P., Allen, P., Stanley, C., & Ammann, W. (1991). **Cardiovascular adaptations in Andean natives after 6 wk of exposure to sea level.** *J. Appl. Physiol., 70,* 2650-2655.

Abstract Six male Quechua Indians (34.0 ± 1.1 yr, 159.5 ± 2.1 cm, 60.5 ± 1.6 kg), life-long residents of La Raya, Peru (4,350 m altitude with an average barometric pressure of 460 Torr), were studied using noninvasive methods to determine the structural and functional changes in the cardiovascular system in response to a 6-wk deacclimation period at sea level. Cardiac output, stroke volume, and left ventricular ejection fractions were determined using radionuclide angiographic techniques at rest and during exercise on a cycle ergometer at 40, 60, and 90% of a previously determined maximal O_2 consumption. Subjects at rest were subjected to two-dimensional and M-mode echocardiograms and a standard 12-lead electrocardiogram. Hemoglobin and hematocrit were measured on arrival at sea level by use of a Coulter Stacker S^+ analyzer. After a 6-wk deacclimation period, all variables were remeasured using the identical methodology. Hemoglobin values decreased significantly over the deacclimation period (15.7 ± 1.1 to 1.35 ± 1.2 g/dl: $P < 0.01$). The results indicate that the removal of these high-altitude-adapted natives from 4,300 m to sea level for 6-wk results in only minor changes to the cardiac structure and function as measured by these noninvasive techniques.

Money, K. E., & Cheung, B. S. K. (1991). **Alterations of proprioceptive function in the weightless environment.** *J. of Clinical Pharmacology, 31*(10), 1007-1009.

Abstract The alterations of proprioceptive function in the weightless environment will be discussed. The proprioceptive function is the function of those sensory systems that have their sensory receptors in muscles, tendons, and joints. These receptors function as part of the system that gives us perception of where limbs are, positions, angles and motions, and so on. Proprioceptors also assist, independently of anything that is conscious, to provide reflex control of limbs generally, in the aid of maintaining body balance and posture.

Moore, J. B., Tabborok, B., & Fraser, W. D. (1991). **Finite element modeling of sustained +Gz acceleration induced stresses in the human ventricle myocardium.** In *AGARD Conference Proceedings. 516. High Altitude and High Acceleration Protection for Military Aircrew,* Pensacola, Florida: North Atlantic Treaty Organization.

Abstract Due to reports of endocardial hemorrhaging and myofibrillar degradation in swines undergoing high sustained +Gz accelerations, questions axis as to the possibility of cardiac tissue damage in humans subjected to similar +Gz forces. Non-invasive cardiological techniques used during experiments seem too insensitive to provide sufficient data to determine the presence of any

localized cardiac damage. In addition, these tests involve some risk to the subject. Hence, there exists the need for a model to predict possible tissue damage under high sustained +Gz accelerations. This paper presents the development of such a model for the analysis of +Gz induced stresses in the human ventricle myocardium. The model is based on the finite element method where the effects of finite displacements, large strains and nonlinear nearly incompressible material behaviour are accounted for. When experiments cannot be justified the computational model can provide valuable quantitative (gross distortions and predicted stresses) data on the effects of +Gz induced stresses in humans. Ultimately, the goal is to provide some form of cardiac risk assessment for pilots of high performance aircraft.

Paul, M. (1991). **Asymmetric visual deficits at high sustained Gz.** *Aviat. Space Environ. Med., 62*(6), 573-574.

Abstract Occasionally, acceleration research personnel see an individual who experiences consistent asymmetric visual deficits at high sustained Gz (HSG). Recently, one such centrifuge research subject from this laboratory was investigated with transcranial doppler sonography. The results indicate an abnormal circle of Willis which could explain the asymmetric visual deficit at HSG.

Ward, C. A., Yee, D., McCullough, D., & Fraser, W. D. (1991). **Bubble nucleation threshold of decomplemented plasma.** In *AGARD Conference Proceedings. 516. High Altitude and High Acceleration Protection for Military Aircrew,* (pp. 2.1 - 2.4). Pensacola, Florida: North Atlantic Treaty Organization.

Abstract Previous work has indicated that rabbits that are more susceptible to decompression sickness (DCS) are also more sensitive to complement activation by air bubbles, and further that rabbits can be protected from DCS if they are pharmacologically decomplemented before they are subjected to the pressure profile. We have investigated a possible means by which decomplementing a rabbit could protect it from DCS. Since DCS is thought to be produced by bubbles that are formed in the tissues of an animal because of its tissues becoming oversaturated with dissolved gas as the animal undergoes a pressure profile, we have investigated the possibility that decomplementing an animal protects it from DCS by making it more difficult to form bubbles in one of the tissues of primary concern, blood plasma. This investigation was performed with three test liquids: 1) water, 2) native rabbit plasma, and 3) decomplemented rabbit plasma. We find that the threshold for bubble nucleation in water is greater than that in either plasma or decomplemented plasma, but we do not find any difference between the nucleation threshold of the two types of plasma. Thus the indications are that the protection from DCS that results from decomplementing a rabbit does not appear to develop because of a change in the nucleation threshold of the decomplemented plasma.

1992

Bain, B., Jacobs, I., & Buick, F. (1992). **Effect of simulated air combat manoeuvring on muscle glycogen and lactate.** *Aviat. Space Environ. Med., 63,* 505-509.

Abstract Muscle glycogen and muscle and blood lactate were evaluated before and after a +4.0/7.0 Gz simulated air combat manoeuvring (SACM) protocol in the human centrifuge. The subjects were 8 healthy males, age 25-43 y. Muscle glycogen and lactate were determined from biopsies of m. vastus lateralis in 6 subjects and whole blood lactate was analyzed in finger-tip blood samples from 8 subjects. G-tolerance time was 256 ± 33 s

(Mean ± SEM). The decrease in glycogen concentration averaged 81 ± 36 mmol • kg^{-1} dry wt. (p=0.07). The rate of glycogen utilization was low, averaging 0.4 ± 0.1 mmol • kg^{-1} • s^{-1}. Muscle lactate increased significantly from 28 ± 2 mmol • kg^{-1} dry wt pre-SACM to 51 ± 4 mmol • kg^{-1} post-SACM. Post-SACM blood lactate was 4.2 ± 0.3 mmol •L^{-1}. Neither final blood nor muscle lactate values nor the difference between pre and post SACM muscle lactate concentrations were related to G-tolerance time. It was concluded that glycogen availability in m. vastus lateralis is not a limiting factor during exposure to headward acceleration of this type and duration. The lactate values, while high, cannot fully explain the muscular fatigue occurring during centrifuge exposures of the type used here. Therefore, the suggestion by others that anaerobic energy metabolism in skeletal muscles is the crucial factor limiting the ability to resist fatigue during exposure SACM is not supported and is likely an oversimplification of a much more complex problem.

Buick, F. (1992). **Advanced +Gz protection systems and their physiologic bases.** *The Physiologist., (Suppl.) 35,* S158-S161.

Abstract This paper discusses the known physiologic bases of advanced methods for protecting against the effects of headward acceleration (+Gz). The physiologic effects of +Gz leading to reductions in blood pressure at head level are presented first. The second section discusses current anti-G systems. The hypertensive benefits of the anti-G straining maneuver and of the G-suit are due to increases in peripheral vascular resistance. The final section discusses how greater coverage G-suits and positive pressure breathing can improve +Gz tolerance. Greater coverage G-suits delivering up to 3 +Gz of protection were already available during the late 1940's and provide the basis for current efforts to improve on the standard 5-bladder design. Positive pressure breathing increases blood pressure but the full potential of this method awaits development of the optimum pressure schedule.

Buick, F., Hartley, J., & Pecaric, M. (1992). **Maximum intrathoracic pressure with anti-G straining maneuvers and positive pressure during +Gz.** *Aviat. Space Environ. Med., 63,* 670-676.

Abstract Positive pressure breathing during +Gz (PBG) and anti-G straining maneuvers (AGSM) each improve +Gz tolerance by increasing blood pressure through increases in intra-thoracic pressure, but the maximal intra-thoracic pressure from their combined effect is not known. Six subjects performed: (i) maximal AGSM at +1 Gz; (ii) assisted PBG (constant 60 mm Hg) at +Gz ; (iii) submaximal AGSM at +Gz (enough to maintain peripheral vision); (iv) maximal AGSM at +Gz; and (v) combined PBG and maximal AGSM at +Gz. They wore: TLSS mask/helmet ensemble, CSU-15/P G-suit, and TLSS-style jerkin. Intra-thoracic pressure was measured with a catheter tip pressure transducer in the esophagus (Pes). The change in gastric pressure was also measured (ΔPga). For both Pes and ΔPga, there were no significant differences among experimental conditions (i), (iv) and (v). Group mean Pes and ΔPga in these 3 conditions were 139 and 197 mm Hg, respectively. The similar results between maximal AGSM, and maximal AGSM and PBG are explained by: (i) limited support from the thoracic counter-pressure garment, and (ii) the characteristics of the respiratory system.

Cheung, B., Money, K., Howard, I., Kirienko, N., Johnson, W., Lackner, J., Dizio, P., & Evanoff, J. (1992). **Human ocular torsion during parabolic flights - an analysis with scleral search coils.** *Exp. Brain Res., 90*(1), 180-188.

Abstract Rotation of the eyes about the visual axis is known as ocular torsion. A lateral inclination (a "roll") of the head induces ocular torsion in the opposite direction, a response known as ocular counterrolling. For six subjects, we recorded the static (head still) and dynamic (head in oscillatory roll motion) ocular torsion in normal 1g condition and also during the microgravity and hypergravity periods of parabolic flight, using the electromagnetic scleral search coil technique. With the head still, the direction and magnitude of torsion that occurred in response to microgravity and hypergravity differed substantially from one individual to another, but there was a significant difference in torsional magnitude between the microgravity and hypergravity periods, for all static head positions including the upright position.

Under normal 1 g conditions, counterrolling compensated for about 16% of (voluntary) static head roll, while dynamic counterroll was much larger, up to 36% of head roll at 0.55 Hz. With increasing frequency of head oscillation between 0.33 Hz and 0.55 Hz, the gain of counterrolling increased and there was no change in the phase relationship. The gain of dynamic counterroll (in response to voluntary head rolling) was not significantly less in hypogravity, suggesting that on the ground at these frequencies the contribution of gravity and gravity receptors to this reflex is redundant: this reflex is probably driven by the semicircular canals. In some subjects, the torsional displacement in microgravity is accompanied by micro-torsional oscillatory motion.

Cheung, B. S. K., & Money, K. E. (1992). **The influence of age on susceptibility to motion sickness in monkeys.** *J. of Vestibular Research, 2,* 247-255.

Abstract A longitudinal study on the effects of age on the susceptibility to motion sickness in the squirrel monkey , was carried out over a 10-year period (1982-91). The typical life-span of squirrel monkeys is 15 years. Ten mature male squirrel monkeys of the Bolivian subspecies were found to be susceptible to motion sickness induced by a combination of vertical oscillation at 0.5 Hz and horizontal rotation at 25 rpm in a visually unrestricted environment. Signs of motion sickness were quantified according to a rating scale based on Graybiel's diagnostic criteria. Latency to vomiting/retching and severity of sickness obtained from year 1 (baseline), 3, 5, 7 and 10 were subjected to repeated-measures design analysis. There were no significant differences in the susceptibility level (as measured by latency to vomiting/retching) in the monkeys throughout the 10 year period. The habituation to 7 consecutive daily exposures remained the same throughout the same period. We conclude that, in the squirrel monkeys, there is no change in susceptibility to motion sickness with aging. Our data suggest that it is not age that has an effect on susceptibility, but rather the development of behavioural strategies for coping with provocative motion.

Cheung, B. S. K., Money, K. E., Kohl, R., & Kinter, L. (1992). **Investigation of anti-motion sickness drugs in the squirrel monkey.** *J. of Clinical Pharmacology, 32,* 163-175.

Abstract Early attempts to develop an animal model for anti-motion sickness drugs, using dogs and cats, were unsuccessful. Dogs did not show a beneficial effect of scopolamine (probably the best single anti-motion sickness drug for humans thus far) and the findings in cats were not definitive. The authors have developed an animal model using the squirrel monkey (Saimiri sciureus) of the Bolivian phenotype. Unrestrained monkeys in a small lucite cage were tested in an apparatus that induces motion sickness by combining vertical oscillation and horizontal rotation in a visually unrestricted laboratory environment. Signs of motion sickness were scored using a rating scale. Ten susceptible monkeys (weighing 800–1000 g) were given a

total of five tests each, to establish the baseline susceptibility level. Based on the anticholingeric activity of scopolamine, the sensitivity of squirrel monkey to scopolamine was investigated, and the appropriate dose of scopolamine for this species was determined. Then various anti-motion sickness preparations were administered in subsequent tests: 100 mg scopolamine per monkey; 140 mg dexedrine; 50 mg scopolamine plus 70 mg dexedrine; 100 mg scopolamine plus 140 mg dexedrine; 3 mg promethazine; 3 mg promethazine plus 3 mg ephedrine. All these preparations were significantly effective in preventing motion sickness in the monkeys. Ephedrine, by itself, which is marginally effective in humans, was ineffective in the monkeys at the doses tried (0.3–6.0 mg). The squirrel monkey appears to be a good animal model for antimotion sickness drugs. Peripherally acting antihistamines such as astemizole and terfenadine were found to be ineffective, whereas flunarizine, and an arginine vasopressin V1 antagonist, showed significant activity in preventing motion sickness.

Day, D. R. (1992). ***Partial Compliance Testing of Automotive Infant Restraint Systems to Canadian Motor Vehicle Safety Standard 213.1 (1992).*** (DCIEM 92-58). Defence and Civil Institute of Environmental Medicine.

Abstract The test procedures and results of a series of impacts using the Impact Study Facility's HyGe crash simulator are presented. This study was a portion of a contract with Transport Canada undertaken in 1991. The objective was to determine the compliance of all commercially-available automotive infant carriers in Canada, according to the regulations for buckle and dynamic testing only, in the Canadian Motor Vehicle Safety Standard (CMVSS) 213.1, "Infant Seating and Restraint Systems". The pertinent regulations for infant carrier compliance are given, and the test procedures that were adopted for each regulation of the standard are explained. The method of interpreting the regulations is given in detail, along with recommendations proposed by DCIEM for amendments to the standard, and to the laboratory test procedures.(Remainder deleted on account of PB security rating)

Ducharme, M. B., & Tikuisis, P. (1992). **Convective heat transfer from blood in human forearm during cold water immersion.** In K. R. Diller & A. Shitzer (Eds.), *Macroscopic and Microscopic Heat and Mass Transfer in Biomedical Engineering.* (pp. 169-178). New York: Elsevier Press.

Abstract The limbs contribute about half of the total body heat loss during cold water immersion in absence of shivering. It has been reported that the major portion of heat loss from the limbs (70 to 80%) is attributed to the local metabolic heat production of the tissue, and that the balance originates from the convective heat transfer between blood and tissue These results, however, contrast with recent data obtained in our laboratory which indicate a greater role to the convective heat transfer during cold water immersion. The objective of the present study was to investigate the relative contribution of convective heat transfer in the forearm to the total forearm heat loss during cold water immersion. Each subject immersed his forearm for 3 hours in a well-stirred water bath maintained at 20°C. At the end of the 3-h immersion when a steady-state tissue temperature condition was achieved, an arterial cuff fixed on the distal portion of the upper arm was inflated to 250 mmHg for 30 min to occlude completely the arterial blood supply to the forearm. The heat loss from six evenly spaced locations on the forearm (distal ventral and dorsal, medial ventral and dorsal, and proximal ventral and dorsal portions of the forearm) were recorded continuously by using recalibrated heat flux transducers. The data show that at the end of the 30 min of arterial occlusion,

the forearm heat loss had decreased by an average of 43% for the proximal locations, by 64 % for the medial locations, and by 82% for the distal locations on the forearm. These reductions in heat loss represent, respectively, transitions of 57, 86, and 98% towards steady-state. Steady-state values of heat loss were estimated by applying the Q_{10} rule for metabolic heat production. These results suggest that the major portion (≈80%) of the forearm heat loss during cold water immersion originates from the convective heat transfer between blood and tissue, which is in opposition with the previously reported values.

Goodman, L., Fraser, W. D., Eastman, D. E., & Ackles, K. N. (1992). **Cardiovascular Responses to positive pressure breathing using the Tactical Life Support System.** *Aviat. Space Environ. Med., 63,* 662-669.

Abstract The improved protection afforded by the Tactical Life Support System (TLSS) vs. other partial pressure ensembles has not been reported with respect to the cardiovascular effects of positive pressure breathing (PPB). Nine seated subjects wearing TLSS were exposed to 30, 50 and 70 mmhg PPB (breathing air) with 4 x this pressure in the G-suit. Experiments were conducted at ground-level in order, separated by 4 minutes rest and preceded by a 1 min. control period. Stroke and Cardiac volumes (SV, CO) were determined by impedance cardiography. MAP was directly related to PPB level, increasing by 23%, 32% and 47% for each PPB level, respectively ($P < .01$). HR, SV and CO were unaffected after 4 min. of 30, 50, and 70 mmhg PPB. The results indicate that cardiovascular function decay is less severe than that reported using other PPB ensembles at similar PPB levels. Improved protection is most likely due to the greater pressurization of the G-suit and the 45% greater bladder coverage in the leg bladders, leading to restored venous return and SV.

Goodman, L. S., Walters, M. B., & McKenzie, D. C. (1992). **Inotropic medication causes shift in exercise anaerobic threshold in chronic heart failure patients.** *Am. J. Noninvas. Cardiol., 6,* 28-43.

Abstract To determine if the gas exchange anaerobic threshold (GeAT) is altered by increases in cardiac function, 7 chronic heart failure (CHF) patients (age 56.4 ± 7.6 years) were studied by withdrawal and subsequent reintroduction of inotropic medication, digoxin, to evaluate the sensitivity and feasibility of utilizing GeAT during exercise testing as an additional marker of improved cardiac function. Treadmill tests using a modified Naughton treadmill protocol were done 1 week apart. Blood sampling was done prior to each exercise session to determine digoxin levels. Expired gases were collected using an automated metabolic measurement cart. GeAT was determined by examination of the plots of O_2 consumption ($\dot{V}O_2$) versus minute ventilation (V_E), as well as end-tidal O_2 and CO_2. Dead space/tidal volume ratios (V_D/V_T) were calculated from expired gas variables at submaximal and peak exercise levels. Peak exercise rate pressure product increased from 18.7 to 22.7 bpm X mm Hg X 10^{-3} on, digoxin. $\dot{V}O_2$ peak and relative GeAT ($GeAT_{rel}$) were unchanged with digoxin (1.50 ± 0.58 to 1.60 ± 0.48 $l \cdot min^{-1}$, and from 70.3 ± 14.6 to 76.7 ± 11.3% of $\dot{V}O_2$ peak, respectively). Absolute GeAT ($GeAT_{abs}$) increased from 1.07 ± 0.39 to 1.23 ± 0.39 1-min-i ($p < 0.01$) when on digoxin. No changes in V_D/V_T were observed at submaximal versus maximal exercise, nor with digoxin, suggesting that altered ventilation/perfusion imbalances were not related to the increased V_E and GeAT during exercise under the off- or on-digoxin conditions. These data suggest that although $\dot{V}O_2$ peak remains relatively unchanged with digoxin, the increase in

$GeAT_{abs}$ (reflecting postponed skeletal muscle anaerobic metabolism) might constitute a more sensitive noninvasive marker of changes in blood flow and exercise capacity in CHF patients than $\dot{V}O_2$ peak. Since peak systolic blood pressure increased on digoxin, GeAT might reflect increased myocardial function.

Landolt, J. P., Light, I. M., Greenen, M. G., & Monaco, C. (1992). **Seasickness in totally-enclosed motor-propelled survival craft: Five offshore oil rig disasters.** *Aviat. Space Environ. Med., 63,* 138-144.

Abstract Five mobile offshore drilling unit disasters—Alexander L. Kielland, Ocean Ranger, Vinland, Ocean Odyssey, and Rowan Gorilla I—were studied to assess the degree to which seasickness occurs and endangers the lives of occupants of totally-enclosed motor-propelled survival craft (TEMPSC). Thousands of other peacetime marine incidents were reviewed and a literature search was conducted to assess the same seasickness problem. The one reported death in the Vinland abandonment appears to be the only one that could be associated, even remotely, with seasickness. It cannot be established whether or not seasickness contributed to the cause of death in the case of the Ocean Ranger victims, but it did occur in 75% or more of TEMPSC occupants in the other four rig disasters. It has occurred both in relatively calm waters of 1-m wave height and in severe seas of 15-m height. Evacuees in an intact TEMPSC are able to survive many hours of severe seas; consequently, they should not be rescued until the weather and sea conditions improve. Moreover, practical survival training and good leadership is a principal cornerstone in the amelioration of seasickness.

Landolt, J. P., & Monaco, C. (1992). **Seasickness in totally-enclosed motor-propelled survival craft: Remedial measures.** *Aviat. Space Environ. Med., 63,* 219-225.

Abstract Totally-enclosed motor-propelled survival craft (TEMPSC) are used to evacuate the crews of mobile offshore drilling units in emergencies. The small size and flat bottom of the TEMPSC pre-dispose most occupants to seasickness, even in relatively calm waters. This paper discusses efforts required to improve the well-being of occupants in terms of reducing seasickness, dehydration, hypothermia, anxiety, and the other factors that contribute to loss of comfort and the will to survive. Specific recommendations include the provision of climatic control to regulate temperature, remove odors and provide fresh air; potable water, electrolytes, and survival rations; and an ample supply of motion sickness bags. Overcrowding should be avoided. Anti- motion-sickness drug therapy to control vomiting should be administered in two ways: initial injection of intramuscular scopolamine for fast action followed by a transdermal ear patch for long-term protection. Leadership and seasickness management should be requisite survival training for all oil rig workers.

MacDougall, J. D., McKelvie, R. S., Moroz, D. E., Sale, D. G., McCartney, N., & Buick, F. (1992). **Factors affecting blood pressure during heavy weightlifting and static contractions.** *J. Appl. Physiol, 73,* 1590-1597.

Abstract Brachial arterial pressure was directly recorded in 31 healthy male volunteers through protocols examining the effects of the Valsalva maneuver, muscle size and strength, contraction force, contraction type (concentric, isometric, eccentric), changes in joint angle, and muscle fatigue on the blood pressure response to resistance exercise. Weight lifting at the same relative intensity produced similar increases in blood pressure, regardless of individual differences

in muscle size or strength. Concentric, isometric, or eccentric exercise at the same relative intensity caused similar increases despite differences in force production. In weight lifting, the greatest increase in blood pressure occurred at the joint angle corresponding to the weakest point in the strength curve and the least at the angle corresponding to the strongest point. Isometric contractions of the same relative intensity at different joint angles produced identical blood pressure despite differences in absolute force production. When subjects attempted to maintain a maximum isometric contraction for 45 s, the blood pressure increase remained the same despite a marked diminution in force. Thus the magnitude of the blood pressure response depends on the degree of effort or central command and not actual force production. A brief Valsalva maneuver, which exaggerates the increase in blood pressure, is unavoidable when desired force production exceeds ~80% maximum voluntary contraction.

Paul, M., & Gray, G. W. (1992). **The Effect of Captopril on Tolerance to +Gz.** *Aviat. Space Environ. Med., 63,* 706-708.

Abstract Recently, there has been considerable interest in whether or not captopril can be used to treat hypertensive pilots without compromising their operational efficiency. A counterbalanced double blind crossover protocol was used to administer 25 mg of captopril or placebo b.i.d. in identical capsules to 7 fit normo-tensive subjects from the acceleration research panel. The five males and two females took each course of capsules for four days prior to G-tolerance assessment and waited one week for drug washout after assessment on their first condition prior to commencement of the second course of capsules. The subjects did not wear G-suits. The group G-tolerances are listed as mean ± sem; during relaxed gradual onset runs (GOR) 3.89 ± .14 on placebo and 3.60 ± .10 on captopril (p=.03, paired t-test). Corresponding results for relaxed rapid onset runs (ROR) were 3.36 ± .17 on placebo and 3.33 ± .18 on captopril (p=.21, Wilcoxon signed ranks test). The straining tolerances during GOR runs were 7.21 ± .25 on placebo and 6.83 ± .27 while on captopril (p=.05, paired t-test). Given the relatively low dosage and the significant compromise of G-tolerance on both relaxed and straining GOR runs, the use of captopril in fighter aircrew is contra-indicated. However, pending the results of comprehensive research into the performance consequences of captopril on such parameters as reaction time, vigilance, and logical reasoning, captopril may prove to be acceptable for use in transport and helicopter aircrew.

Pecaric, M., & Buick, F. (1992). **Determination of a pressure breathing schedule for improving +Gz tolerance.** *Aviat. Space Environ. Med., 63,* 572-578.

Abstract A base of empirical data for developing optimal pressure breathing during +Gz (PBG) schedules is lacking. Relaxed +Gz-intensity tolerance with PBG was measured during gradual +Gz-onset rate centrifuge profiles using standard lightbar criteria. Constant PBG levels ranging from 18-73 mm Hg were randomly assigned. G-suit pressure followed the standard or an increased inflation schedule. Nine subjects wore a jerkin, CSU-15/P G-suit, and TLSS helmet and mask. With mean mask cavity pressures of 0, 18, 38, 60, and 73 mm Hg, corresponding +Gz-tolerances (mean ± sem) were: +5.3 ± 0.2, +5.8 ± 0.1, +6.6 ± 0.2, +7.3 ± 0.3, and +7.5 ± 0.3 Gz (linear correlation, r=0.994). Increased G-suit pressure did not change the +Gz-tolerance improvement with PBG. The inverse of individual subject regression slopes ranged from 22.6 to 58.1 mm Hg/+Gz. Considering additional factors and adequate +Gz protection for all subjects while relaxed, the proposed schedule would apply 42 mm Hg PBG/+Gz beginning at +3.3 Gz with a maximum pressure of at least 73 mm Hg.

1993

Case, C., Cheung, B., Fry, M., Garshnek, V., Money, K., Smith, G., Uri, J., & Winisdoerffer, F. (1993). **Human factors and physiological aspects of the Mars mission.** *Acta Astronautica, 31,* 73-85.

Abstract An interplanetary space flight or habitation of a foreign planet for long durations can subject the crew to debilitating, injurious and possibly fatal, stresses. Some of these stresses are radiation, hypogravity, isolation/confinement, toxicity, and mission specific environmental conditions. In order to be sure that the mission has a high probability of succeeding, it will be necessary to expand human knowledge of these stresses and their effects over time before undertaking such a flight. At the present time, upon return to Earth after long duration flights, Soviet cosmonauts have been unable to stand or walk and are routinely carried away on stretchers. Better physical condition will be required of astronauts upon landing on Mars.

The planning for the mission should also include consideration of habitability of the environments, crew selection and performance, sociological issues, life support, environmental health, and management of crises and illnesses. The accepted level of risk (possibly 3% risk of catastrophe) needs to be decided. We must realize that, inherently, risk cannot be totally eliminated and should not be denied; missions should be designed with prudent levels of risk. The best way to manage the levels of risk for a mission is to understand the environment and the conditions of that mission, how a human will be affected by and perform in that environment, and the mitigating benefits of control measures.

Cheung, B. S. K., Money, K. E., & Howard, I. P. (1993). **Human gaze instability during brief exposure to reduced gravity.** *J. Vestibular Res., 4*(1), 17-27.

Abstract The stability of gaze in three dimensions (horizontal, vertical and torsional) was investigated with the electromagnetic scleral search coil technique during the microgravity phase of parabolic flights under two visual fixation conditions: fixation on a real target and on an imagined target. Subjects were secured upright with the head immobilized by a dental bite. There were torsional eye movements in response to the imposition of reduced gravitoinertial forces under both visual fixation conditions. The pattern of these movements was consistent with our previous findings on six other subjects. No significant horizontal eye movements were observed in either fixation condition. Under the condition of fixation on an imagined target, direction-specific vertical nystagmus was observed with slow phase directed upwards during transition from hypergravity to microgravity. The slow phase was directed downwards during transition from microgravity to hypergravity, although the nystagmus was of lower frequency and the magnitude of the slow phase velocity appeared to be smaller than during transition from hypergravity to microgravity. The vertical eye movements could be attributed to a change of otolithic stimulation along the subject's z axis since the rate of pitch rotation of the aircraft during parabolic flight was too slow to produce an effective canal input. These kinds of reflex eye movements could degrade vision during manoeuvres or turbulence in flight.

Goodman, L. S. (1993). ***Physiological protection for aircrew at high altitude: A review of the literature.*** (DCIEM 93-13). Defence and Civil Institute of Environmental Medicine.

Abstract The greater performance characteristics of modern fighter aircraft allow attainment of extreme altitude ceilings. However, the technology of hypoxia protection for aircrew during emergency cabin decompression is only now beginning to keep pace. In fact the altitude performance of modern fighter aircraft is limited by their 1950's-generation oxygen systems. In this review paper, the basic physiology of hypoxia and reduced barometric pressure is first reviewed. The use of positive pressure breathing (PPB) for emergency hypoxia protection, sufficient to allow the pilot to maintain useful consciousness until the aircraft is rapidly descended to safe altitudes, is then discussed in a historical perspective. The gas-exchange physiology and mechanisms whereby the correction or amelioration of hypoxia is achieved are explained, followed by detailed discussion of the pulmonary and cardiovascular disruptions caused by PPB. The means whereby these are prevented, namely by thoracic counterpressurisation and G-suit inflation, are reviewed. More recently developed PPB garment technologies, specifically studies which have demonstrated improved optimization of thoracic and G-suit counterpressurisation and PPB-syncope prevention are reviewed. Finally, a short discussion forecasting future trends in PPB garment research and development is presented.

Goodman, L. S., Fraser, W. D., Ackles, K. N., Mohn, D., & Pecaric, M. (1993). **Effect of extending G-suit coverage on cardiovascular responses to positive pressure breathing.** *Aviat. Space Environ. Med, 64,* 1101-1107.

Abstract The purpose of this study was to compare cardiovascular responses of subjects exposed to long-duration positive pressure breathing (PPB) while wearing a standard (Combat Edge; CE) vs. extended coverage (Tactical Life Support System; TLSS) anti-G suit. Twelve experienced subjects wearing TLSS and CE, were separately exposed to counterbalanced 60, 70, 80 and 88 mmHg PPB for up to 10 continuous minutes. Termination resulted if pre-syncopal symptoms arose. G-suit inflation was 4 x mask/jerkin pressure. Using TLSS, all subjects completed 10 minutes of PPB at all levels, vs. 7 and 5 subjects completing 10 minutes at 80 and 88 mmHg using the CE ensemble, respectively ($P < .001$). Heart rate was significantly elevated at all PPB levels using CE ($P < .0001$) vs. TLSS. Stroke and Cardiac Indexes were significantly lower with CE at all levels vs. TLSS ($P < .0001$), and mean arterial blood pressure failed to be maintained at the 80 and 88 PPB mmHg levels using CE ($P < .0001$). Extended anti-G suits afford superior protection against PPB-induced cardiovascular dysfunction vs. standard ensembles and consequently permit use of higher levels of PPB. This is due to the larger and more uniform application of pressure in the leg G-suit bladders, augmenting venous return and stroke volume.

MacDougall, J. D., McKelvie, R. S., Moroz, D. E., Moroz, J. S., & Buick, F. (1993). **The effects of variations in the anti-G straining maneuver on blood pressure at +Gz acceleration.** *Aviat. Space Environ. Med., 64,* 126-131.

Abstract The increase in blood pressure provided by the standard AGSM is caused by both the contraction of the muscles of the lower body and by an increased intrathoracic pressure due to a respiratory straining (Valsalva) maneuver. This study examined the relative effectiveness and fatiguability of the 2 components at +1Gz and then at +Gz acceleration in a human centrifuge. Brachial arterial pressure was recorded from a pressure-tip transducer in 6 subjects performing isometric leg presses only and on a separate occasion while performing respiratory straining only. Measurements were made over a range of intensities for the leg press contractions and Valsalva maneuvers and were conducted at +1 Gz and during slow and rapid onset runs up to +5 Gz in a human centrifuge. Blood pressure was also

recorded during pulsing or intermittent contractions of the legs. We found it difficult to completely separate the blood pressure response to the leg press component from that of the respiratory straining alone component, since a moderate respiratory straining maneuver usually also accompanied forceful contractions of the legs. We conclude, however, that more than half of the elevation in blood pressure caused by the AGSM can be attributed to contraction of the muscles of the lower body and that this component is less fatiguing than the respiratory straining component. At +1 Gz, a pulsing isometric contraction of the legs was no more effective in elevating blood pressure than a constant isometric contraction over the same duration.

Pecaric, M., Buick, F., & Maloan, J. (1993). *Computer control of an electro-mechanical regulator for providing positive pressure breathing and an electronic G-valve for human +Gz research.* (DCIEM 93-05). Defence and Civil Institute of Environmental Medicine.

Abstract Electronic G-valves and breathing regulators are being incorporated into some life-support systems designed for aircrew protection. The utility of these electronic systems, however, has not reached its full potential in the research environment. An electronically controlled G-valve and electro-mechanical breathing regulator were obtained. A prototype, computer-controlled life-support system interface was developed in the laboratory and evaluated in the centrifuge. The interface was used to provide different schedules for G-suit inflation and positive pressure breathing during +Gz (PBG). Output pressures from both a G-valve and breathing regulator were driven by a voltage proportional to the centrifuge +Gz level (from a computer running instrument-controller software) supplied to the system's electronic control unit. The required voltages were calculated from the pressure schedule defined from the following parameters: (i) cut-in +Gz level; (ii) Δ in pressure/Δ+Gz; and (iii) peak pressure of the schedule. Any G-suit pressure or PBG pressure schedule could be produced. The schedules and the performance of the G-valve and breathing regulator were also evaluated at different +Gz onset rates (0.1 and 3.0 +Gz/sec). G-suit pressure and PBG level accurately tracked the +Gz level. The pressure began, increased, and attained the peak level required in both gradual and rapid +Gz onset conditions for all schedules tested. The outputs of both G-valve and breathing regulator reached the maximum pressure within 0.2 sec of reaching the peak +Gz level. The greatest tracking errors occurred during onset to peak +Gz with 3.0 +Gz/sec profiles. Most of this error was attributed to the slow response of the controller software. Improvements in the speed of the controller via alterations in software and/or hardware are necessary to minimize tracking error produced by rapid onset rates of acceleration. Simultaneous control of both PBG and G-suit schedules using a single computer controller would be ideal. A computer-controlled life-support system interface would facilitate investigations optimizing PBG and /or G-suit pressure schedules, or any other inflation schedule utilized by various anti-G systems.

1994

Bain, B., Jacobs, I., & Buick, F. (1994). **Electromyographic indices of muscle fatigue during simulated air combat manoeuvring.** *Aviat. Space Environ. Med., 65,* 193-198.

Abstract Pilots exposed to high levels of headward (+Gz) acceleration must perform voluntary muscle contractions in order to maintain head-level arterial pressure. To study the possibility that muscular fatigue can limit man's +Gz duration tolerance, electromyographic (EMG) activity and EMG indices of muscular fatigue were measured during a simulated air combat manoeuvring (SACM) centrifuge profile. Eight experi-

enced male volunteers were exposed to a +4-7Gz centrifuge profile until volitional fatigue. Electrical activity (EMG) was recorded in 7 muscles: biceps brachii (BB), latis-simus dorsi (LD), pectoralis major (PM), rectus abdominis (RA), vastus lateralis (VL), biceps femoris (BF) and gastrocnemius (GN). EMG and force during isometric contractions of the same muscles were also recorded at 1G. Root mean square (RMS) and mean power frequency (MPF) were calculated for each second of EMG data. G-tolerance time averaged 256 + 33 s (mean + SD). RMS activity was expressed relative to activity during a maximal muscle contraction. The mean values (%) for each muscle during the 7G plateau were: RA, 30.8; BB, 26.4; LD, 44.0; PM, 48.5; VL, 43.4; BF,31.4; GN, 39.3. The estimated level of contraction relative to a MVC (%) was: RA, 36.6; BB, 30.5; LD, 43.9 and PM, 61.4. There was no significant difference between contraction levels for any of the muscles studied. RMS activity did not increase over time and MPF decreased significantly only in BF and LD, however, these decreases were small. EMG activity and estimated contraction intensities were considered to be low to moderate. These results suggest that it is unlikely that fatigue in the muscles studied would limit G-tolerance time.

Banks, R. D., & Gray, G. W. (1994). **"Bunt Bradycardia": Two cases of slowing of heart rate under negative Gz.** *Aviat. Space Environ. Med., 65,* 330-331.

Abstract Two cases are presented of Canadian Forces pilots who experienced in-flight bradycardia during 15 s of –1 Gz acceleration. The bradycardia was characterized by rapid cardiodeceleration, stable bradycardia, then cardioacceleration during recovery following the -Gz exposure that was slower than the cardiodeceleration. Vagally mediated bradycardia in humans subjected to -Gz acceleration stress has been previously documented in laboratory studies. This bradycardia may be operationally significant since it signifies the presence of other physiological effects that predispose aviators to reduced subsequent +Gz tolerance. Research to investigate the implications of reduced +Gz tolerance following -Gz acceleration is warranted.

Banks, R. D., Grisset, J. D., Turnipseed, G. T., Saunders, P. L., & Rupert, A. H. (1994). **The "push-pull effect".** *Aviat. Space Environ. Med., 65,* 699-704.

Abstract The purpose of this study was to prove or refute previous authors' suggestions that tolerance to +Gz is reduced when preceded by 0 Gz or -Gz. Six males and six females were subjected to one session of acceleration stresses that varied between -2 and +2.25 Gz on the NAMRL Coriolis Acceleration Platform (CAP). At the beginning and end of each session, we exposed the relaxed subjects to identical control segments that were comprised of +1 Gz for 30 s, followed by +2.25 Gz for 15 s, and then return to +1 Gz. Subjects were also exposed to three experimental segments that were comprised of 0, -1, or -2 Gz for 10 s, followed by +2.25 Gz for 15 s, and then return to +1 Gz. Subjects verbally reported any decrements in peripheral vision during exposure to +2.25 Gz. Blood pressure (BP) was reduced during each 15-s period at +2.25 Gz. The minimum BP was progressively lower during the 15-s period as the preexposure experimental conditions became more negative (+1, 0, -1, and -2 Gz). Episodes of peripheral vision loss increased as the preceding -Gz became more negative. BP during exposure to +Gz was significantly affected by the preceding 10-s exposure to -Gz, and is indicative of reduced +Gz tolerance. As this "push-pull effect" may result in unexpected incapacitation, it is relevant to aviation safety.

Cheung, B. S. K., Kohl, R. L., Money, K. E., & Kinter, L. B. (1994). **Etiological Significance of Arginine Vasopressin (AVP) in Motion Sickness.** *J. Clin. Pharmacol., 34,* 664-670.

Abstract There is abundant evidence implicating the role of arginine vasopressin with motion sickness. The effects of AVP analogues on motion sickness were investigated in squirrel monkeys. Two specific V_1 antagonists (SK&F 100273 and SK&F 103561) and three mixed V_1/V_2 antagonists (SK&F 101926; SK&F 105494 and SK&F 104146-D) were tested on 6 highly susceptible monkeys. Intravenous injections of 200 ug of a V_1 antagonist abolished emesis in all 6 monkeys, few prodromal symptoms remained (latency to emesis > 120 minutes, $p < 0.001$). Mixed V_1/V_2 antagonists failed to abolish emesis in all monkeys. However, there was a slight increase in the latency to the first bout of emesis/retching with the mixed antagonists when compared to the baseline. The dose-response relationship and rate of onset of action of the V_1 antagonist (SK&F 100273) were explored. Latency to the first bout of emesis/retching increased to about twice that of the baseline when half of the effective anti-emetic dose was used. The efficacy demonstrated by the specific V_1 antagonists suggests that V_1 receptors may modulate emesis.

Chung, D. W. J., Eizenman, M., Cheung, B. S. K., & Frecker, R. C. (1994). **Estimation of Ocular torsion with dynamic changes in pupil size.** In *16th Annual Internation Conference IEEE Engineering in Medicine and Biology Society.,* Baltimore, Maryland: IEEE.

Abstract The accuracy of estimating ocular torsion by the cross-correlation technique [3] was evaluated in five healthy subjects. During the study, the subjects fixated a stationary target while their pupil size was manipulated by increasing/decreasing the amount of light falling on their retinas. For all subjects, ocular torsion estimates had an overall mean value of 0.22° and a standard deviation of 0.89°. We suggest that the reasons for the relatively large standard deviations are: a.) physiological torsional oscillations and drift during fixation [4]; and b.) non-radial movements of the iris structure during pupil constriction and dilation. The non-radial movement of the iris structure resulted in different ocular torsion estimates from different regions of the iris. The range of ocular torsion estimates from different regions varied from 0.26° for a 15% increase in pupil radius to as much as 3.0° for a 90% increase in pupil radius.

Day, D. R. (1994). ***Partial Compliance Testing of Automotive Infant Restraint Systems to Canadian Motor Vehicle Safety Standard 213.1 (1994).*** (DCIEM 95-01). Defence and Civil Institute of Environmental Medicine.

Abstract The test procedures and results of a series of impacts using the Impact Study Facility's HyGe crash simulator are presented. This study was a portion of a contract with Transport Canada undertaken in 1993. The objective was to determine the compliance of all commercially-available automotive infant carriers in Canada, according to the regulations for buckle and dynamic testing only, in the Canadian Motor Vehicle Safety Standard (CMVSS) 213.1, "Infant Seating and Restraint Systems". The pertinent regulations for infant carrier compliance are given, and the test procedures that were adopted for each regulation of the standard are explained. The method of interpreting the regulations is given in detail, along with recommendations proposed by DCIEM for amendments to the standard, and to the laboratory test procedures. All thirteen carrier models tested met all the standards of the CMVSS.

Day, D. R. (1994). ***Partial Compliance Testing of Automotive Child Restraint Systems to Canadian Motor Vehicle Safety Standard 213 (1993).*** (DCIEM 94-14). Defence and Civil Institute of Environmental Medicine.

Abstract The test procedures and results of a series of impacts using the Impact Study Facility's HyGe crash simulator are presented. This study was a portion of a contract with Transport Canada undertaken in 1992. The objective was to determine the compliance of all commercially available automobile child carriers in Canada, according to the regulations for buckle and dynamic testing only, in the Canadian Motor Vehicle Safety Standard (CMVSS) 213, "Child Restraint Systems". The pertinent regulations for child carrier compliance are given, and the test procedures which were adopted for each regulation of the standard are explained. The method of interpreting the regulations is given in detail, along with DCIEM recommended amendments to the standard and to the laboratory test procedures. All the carriers were tethered and most were tested in both their reclined and upright modes. (Remainder deleted on account of PB security rating)

Day, D. R. (1994). ***Partial Compliance Testing of Automotive Child Restraint Systems to Canadian Motor Vehicle Safety Standard 213 (1994).*** (DCIEM 94-54). Defence and Civil Institute of Environmental Medicine.

Abstract The test procedures and results of a series of impacts using the Impact Study Facility's HyGe crash simulator are presented. This study was a portion of a contract with Transport Canada undertaken in 1993. The objective was to determine the compliance of all commercially available automobile child carriers in Canada, according to the regulations for buckle and dynamic testing only, in the Canadian Motor Vehicle Safety Standard (CMVSS) 213, "Child Restraint Systems". The pertinent regulations for child carrier compliance are given, and the test procedures which were adopted for each regulation of the standard are explained. The method of interpreting the regulations is given in detail, along with DCIEM recommended amendments to the standard and to the laboratory test procedures. All the carriers were tethered and most were tested in both their upright modes. (Remainder deleted on account of PB security rating)

Day, D. R. (1994). ***Partial Compliance Testing of Automotive Infant Restraint Systems to Canadian Motor Vehicle Safety Standard 213.1 (1993).*** (DCIEM 94-17). Defence and Civil Institute of Environmental Medicine.

Abstract The test procedures and results of a series of impacts using the Impact Study Facility's HyGe crash simulator are presented. This study was a portion of a contract with Transport Canada undertaken in 1992. The objective was to determine the compliance of all commercially-available automotive infant carriers in Canada, according to the regulations for buckle and dynamic testing only, in the Canadian Motor Vehicle Safety Standard (CMVSS) 213.1, "Infant Seating and Restraint Systems". The pertinent regulations for infant carrier compliance are given, and the test procedures that were adopted for each regulation of the standard are explained. The method of interpreting the regulations is given in detail, along with recommendations proposed by DCIEM for amendments to the standard, and to the laboratory test procedures. (Remainder deleted on account of PB security rating)

Fraser, W. D., Goodman, L. S., Ackles, K. N., Mohn, D., & Pecaric, M. (1994). **Cardiovascular Responses with Standard and Extended Bladder Coverage G-Suits During Rapid Decompression.** *Aviat. Space Environ. Med., 65,* 209-213.

Abstract This study compared the cardiovascular responses of subjects exposed to 60,000 ft. rapid decompression while wearing the Combined Advanced Technology Enhanced Design "G" Ensemble (COMBAT EDGE or CE) and the Tactical Life Support System (TLSS). Eight subjects were rapidly decompressed from 22,500 ft (6,858 m) to 60,000 ft (18,288 m), once wearing the CE ensemble and once wearing the TLSS ensemble. There were significant differences in heart rate, stroke volume, cardiac index, and mean arterial pressure ($p < 0.0001$), due to garment type, with TLSS providing better cardiovascular support. Oxygen saturation did not decrease to the same degree with CE as with TLSS ($p < 0.0001$). Both TLSS and CE provided sufficient physiological support to maintain oxygen saturation above 65% during the 3-min exposures to 60,000 ft altitude. Short-term physiological support at higher altitudes with greater PPB levels or longer duration excursions at 60,000 ft may not be possible without the greater G-suit bladder coverage and cardiovascular support provided by TLSS-type garments.

Goodman, L. S., Freeman, M. R., Yang, L., Hsia, T. W., & Chan, J. (1994). **Increased G-suit coverage improves cardiac preloading conditions during positive pressure breathing.** *Aviat. Space Environ. Med., 65,* 632-640.

Abstract A miniaturized nuclear probe (MNP) and multiple gated cardiac blood pool imaging (RCBI) were used to measure left ventricular function during positive pressure breathing (PPB) while wearing an extended-coverage (EC) vs. standard-coverage (SC) anti-G suit. Seven subjects were exposed to 4.0 and 9.3 kPa PPB wearing both anti-G suits during 3 minutes of PPB at ground level. Ejection fraction was unchanged using both techniques. The atrial component to diastolic filling was greater with the SC suit ($P < .02$). Using the MNP, end-diastolic and end-systolic volumes declined non-linearly over time at both PPB levels; these declines were was greater with the SC G-suit ($P < .001$). Left ventricular preload declines during PPB. This is attenuated with increased G-suit coverage, confirming prior results using impedance cardiography. RCBI is less sensitive than MNP's for measuring non steady-state cardiac physiology such as PPB.

Goodman, L. S., Goodman, J. M., Hsia, T. W., & Freeman, M. R. (1994). **Measurement of left ventricular function during arm ergometry using the VEST nuclear probe.** *Can. J. Appl. Physiol., 19*(4), 462-471.

Abstract A chest-mounted left ventricular (LV) nuclear probe (VEST^{TM}) for use during an arm and leg ergometry is presented, with a discussion of the validity and reproducibility of LV function measures at rest and exercise. During both arm and leg ergometry in trained subjects, transient changes in LV function/volumes were observed. LV ejection fraction and relative end-systolic and end-diastolic volumes were 25 to 30% less with the arms versus the legs, agreeing with data from other studies using conventional techniques. At peak exercise with both limbs, LV ejection fraction and relative LV end-systolic volume increased, followed by immediate postexercise normalization. The effect was greatest with the arms and reflects the effect of high intramuscular and arterial pressures generated during arm cranking, leading to increased LV afterloading. The VEST^{TM} permits rapid and noninvasive assessment of LV function during arm exercise, avoiding the limitations of other techniques.

Paul, M., & Fraser, W. D. (1994). **Performance During Mild Acute Hypoxia.** *Aviat. Space Environ. Med., 65,* 891-899.

Abstract The controversy regarding the effects of mild hypoxia on learning performance needs to be resolved, since this may be affecting flight operations and safety. This study examined the ability to learn new tasks at low altitudes. Naive subjects (n = 144) performed spatial orientation (Manikin), serial choice reaction time (SCRT) and logical reasoning (Baddeley) tasks at ground level and at altitudes of 1,524 m (5,000 ft), 2,438 m (8,000 ft), 3,048 m (10,000 ft), and 3,658 m (12,000 ft), at rest or during exercise ($\dot{V}O_2$ = 600 ml O_2 • min -1) in a hypobaric chamber. Each task was performed over four serial repetitions (blocks) and presented at ground level or one of the four test altitudes in a first session, and in the reverse order in a second session. Performance for the Manikin and SCRT tasks improved significantly ($p < 0.0001$) over the 4 blocks. No significant difference was found between the corresponding 4 blocks of the first session in resting and exercising subjects tested at ground level before altitude compared to altitude before ground level. In general, RT for the 3 tasks were faster in resting than in exercising subjects. These results indicate that the ability to learn new tasks is not impaired by mild hypoxia at altitudes of up to 3,658 m. We detected a biphasic response to altitude in LRT and SCRT performance, but not for Manikin performance.

Pecaric, M., Jackson, M. T., Frampton, R. R., Maloan, J., & Buick, F. (1994). ***A prototype computer controlled life support system for independent regulation of G-suit and PBG pressures.*** (DCIEM 94-57). Defence and Civil Institute of Environmental Medicine.

Abstract Electronic control of the G-valve and pressure breathing regulator is being implemented in some advanced life support systems used in aircrew protection. This technological improvement, however, has not reached its full potential in the research environment. A computer-controlled life support system interface providing programmable schedules for G-suit inflation and positive pressure breathing during +Gz (PBG) was developed. Output pressures from a G-valve and pressure breathing regulator (Carleton Technologies) were controlled by a Macintosh computer running LabVIEW software. Required pressures were determined as functions of single or multiple control inputs (i.e. +Gz level, a pressure signal, time, etc.). Subject safety was ensured via hardware limitations and status checks incorporated into the software. Experiments conducted at +1 Gz and at various +Gz levels evaluated the computer software-life support hardware interface. Tests verified the system provided accurate and reproducible G-suit and mask pressures. Time of inflation, peak pressure attained, and deflation rate were effectively controlled at all +Gz levels using open-loop algorithms. Independent control of G-suit and PBG pressures was successfully accomplished. The ability to alter the pressure schedules independent of +Gz or time allows comprehensive control over all parameters necessary to conduct acceleration research involving advanced life support systems.

1995

Bain, B., Jacobs, I., & Buick, F. (1995). **Is there central fatigue during simulated air combat maneuvering?** *Aviat. Space Environ. Med., 66*(1), 1-5.

Abstract This study tested the hypothesis that repeated exposure to high levels of +Gz acceleration, in conjunction with repeated execution of an Anti-G Straining Maneuver (AGSM), causes central fatigue, presumably by impairing central nervous system (CNS) function. We speculated that central fatigue would impair the ability to recruit sufficient musculature at the intensity

required to perform an adequate anti-G straining maneuver. Central fatigue was evaluated by measuring maximal force generation and surface electromyographic activity of leg extensor muscles before, during, and immediately upon termination of an SACM, and comparing these values to those obtained when the muscles were electrically stimulated during maximal voluntary contractions (MVCs). We assumed that any observed increase in force generation during the MVCs, caused by the stimulation, would indicate central fatigue. G-tolerance time was 230 ± 172 s. Hypoxia was induced by the SACM as the arterial oxygen saturation decreased significantly from 97% to 90%. In spite of this hypoxia, there was no significant change in MVC force when the pre- and post-SACM values were compared. Electrical stimulation during the MVC's did not cause an increase in force generation. The average forces generated during the +7 Gz phase of the SACM were only about 35% of MVC force. This force value did not change significantly during the SACM. The results indicate that the inability to continue to perform the AGSM during an SACM is not likely clue to central fatigue or to fatigue of the large skeletal muscle groups we have examined. Taken together with other recent studies, all indicating that the force levels generated in large muscle groups during an SACM are submaximal, these results question the rationale for advocating strength training for the purpose of improving tolerance of +Gz acceleration forces.

Banks, R. D., Grisset, J. D., Saunders, P. L., & Mateczun, A. J. (1995). **The effects of varying time exposure to -Gz on subsequent decreased +Gz physiological tolerance (push-pull effect).** *Aviat. Space Environ. Med., (in press).*

Abstract INTRODUCTION. Previous studies have demonstrated decreased +Gz tolerance when preceded by 0 Gz or -Gz, referred to as the "push-pull effect." The purpose of this experiment was to observe the effect of varying time duration at -Gz on the push-pull effect.
METHODS. During single sessions, 6 subjects (3 males, 3 females) were subjected to 5 relaxed exposures to +2.25 Gz on the NAMRL Coriolis Acceleration Platform (CAP). The first and last exposures were control runs that were preceded by +1 Gz. Each experimental run was preceded by -2 Gz for 2, 5, or 15 s: Blood pressure (BP) was monitored using the Finapres at the level of the clavicle. Visual light loss was assessed at +2.25 Gz using a light bar.
RESULTS. Mean BP was significantly reduced when the +2.25 Gz exposures were preceded by -2 Gz. Following 15 s of -2 Gz, mean BP decreased more and was slower to recover than for 2 and 5 s of -2 Gz. Reported incidents of visual light loss were: 1 following 2 s, 2 following 5 s, and 4 following 15 s at -2 Gz. There were no reports of visual light loss during control runs.
CONCLUSION. During relaxed conditions, the push-pull effect is augmented by increasing duration of the preceding -Gz.

Bock, O., Arnold, K. E., & Cheung, B. S. K. (1995). **Performance of a simple task in hypergravity. I. Overall accuracy.** *Aviat. Space Environ. Med., (in press).*

Abstract Background: It is known that visuo-motor performance is affected by exposure to hyper-gravity (hyper-G), but the underlying mechanisms remain to be determined; the present study investigated the role of target mislocalization. Method: Subjects pointed before, during and after exposure to hyper-G at targets without seeing their hand. Target positions were displayed a) throughout each pointing response, b) before response onset, or c) in normal gravity prior to a set of movements. Results & Conclusions: For all display conditions, subjects pointed higher in hyper-G than in normal gravity *from the first movement on.* We attribute the discrepancy between this find-

ing and previous results (8,12) to different movement strategies. The effects of hyper-G on pointing performance were small but sustained when targets were displayed before or throughout each movement, but they were large and transient when targets were memorized in normal-G. We concluded that too high pointing in hyper-G can not be simply explained by the "elevator illusion", and proposed a tentative interpretation based on known perceptual deficits.

Bock, O., Arnold, K. E., & Cheung, B. S. K. (1995). **Performance of a simple task in hypergravity. II. Detailed response characteristics.** *Aviat. Space Environ. Med., (in press).*

Abstract Background: Literature proposes three hypotheses for impaired movement execution in hyper-G. The present study attempted to discriminate between these hypotheses by comparing kinematic characteristics and final accuracy of pointing movements in different gravity levels. Method: Subjects pointed without seeing their hand at targets presented before, during and after exposure to hyper-G. Results: After factoring out movement amplitude, peak vertical velocity and the skewness of velocity profiles tended to increase, while movement duration tended to decrease with increasing G-level. Furthermore, final response position was slightly *less* modulated by target position in hyper-G than in normal-G. Conclusion: Although not all findings reached statistical significance, the observed pattern of results corroborates the hypothesis (2) that the motor system re-interprets hyper-G as increased arm weight.

Buick, F., Wood, E. H., Pecaric, M., & Maloan, J. (1995). **The Methods for Measuring physiological responses and protection in man exposed to high +Gz.** In *NATO/AGARD/AMP,* (submitted for publication), Neuilly-sur-Seine, France:

Abstract The often-used subjective measurements of +Gz tolerance are inadequate because they are prone to subjective bias and cannot document the time-dependent changes in the reacting physiology. This lecture describes non-invasive, objective measurements used to measure the human subject's physiological status, to monitor physiological reactions in order to compare the +Gz protective value of various +Gz countermeasures, and to measure endpoints which will guide the termination of +Gz exposure.

Cheung, B., Money, K., Wright, H., & Bateman, W. (1995). **Spatial disorientation implicated accidents in Canadian Forces 1982-1995.** *Aviat. Space Environ. Med., (in press).*

Abstract In a recent survey of CF18 aircrew human factors, 44% of pilots reported experience with disorientation (SD) of which 10% had experienced more than three episodes. In order to investigate further, we have completed a retrospective study of SD implicated category A accidents (where an aircraft is destroyed, declared missing or damaged beyond economic repair) in the Canadian Forces (CF) during 1982-92. An overview of all SD occurrences (including accidents and incidents) across aircraft types is also presented. Information was gathered concerning the genesis and severity of disorientation so that research effort and pilot training could be appropriately implemented. Mishap investigation summaries involving category A accidents where SD was implicated were obtained from the CF Directorate of Flight Safety and reviewed. We also examined in detail the Board of Inquiry Reports of these accidents. The role of disorientation in these accidents was as-

sessed. There were 62 category A accidents between 1982-92 and in 14, SD had been assigned as a possible cause factor in the accident records. When divided into the categories of Recognized SD, Unrecognized SD and Incapacitating SD , all but two fell into the category of unrecognized SD (the pilots were unaware of the disorientation). Eleven of the SD accidents involved a total loss of 24 lives. The majority of the accidents happened during the day, and pilots' cumulative flying experience did not appear to be a significant factor. According to our assessment, there were two episodes of vestibular origin, involving the somatogravic illusion. Three episodes of disorientation occurred over frozen lakes and one over glassy water and one over ocean. Two accidents occurred during tactical training involving more than one aircraft. The causes of two accidents remain undetermined, with SD listed along with other possible cause factors. The suggestion follows that more research effort and pilot education and training should be placed on somatogravic illusions and visual limitations under adverse flying conditions and pilots should be made more aware of these fourteen accident scenarios.

Cheung, B. S. K., Money, K. E., & Howard, I. P. (1995). **Dynamics of torsional optokinetic nystagmus under altered gravitoinertial forces.** *Experimental Brain Research, 102,* 511-518.

Abstract The purpose of the present study was to investigate the influence of varying gravitoinertial (Gz) forces on torsional optokinetic nystagmus during parabolic flights. Using the scleral search-coil technique, we measured the gain and phase lag of torsional optokinetic nystagmus (OKN) induced by a hemispherical visual display rotating about the roll axis either at constant velocity or sinusoidally at various frequencies during level flight, hypogravity, and hypergravity. Compared with level flight, there was a significant increase of slow-phase eye velocity during hypogravity and an increase in nystagmic frequency. An absence of well-developed torsional optokinetic after nystagmus was observed in all three gravity conditions. Other characteristics included a lack of a slow rise component. These data suggest that otolith inputs do affect torsional OKN. The absence of well-developed torsional optokinetic after nystagmus suggests that the velocity storage pathways do not contribute significantly to the torsional OKN system in humans.

Goodman, L. S., McKenzie, D. C., Nath, C. R., Schamberger, W., Taunton, J. E., & Ammann, W. C. (1995). **Left ventricular adaptations in walking/jogging vs. aerobic circuit-trained cardiac patients.** *Can J. Appl. Physiol., 20*(2), 179-198.

Abstract The purposes of this study were: (1), to determine whether in coronary artery disease (CAD) patients maintained on medications, left ventricular (LV) function adapts differently in response to 6 months of either walking/jogging (legs-only; LO) or aerobic circuit training (arms and legs; AL), and (2), to determine whether a transfer of fitness to the untrained arms in the LO group is related to a central (cardiac) training effect. A control group (C) was also studied. Peak oxygen uptake for arm and leg ergometry, and submaximal and maximal cycle ergometry tests using radionuclide cardiac angiography (RNA) were performed before and after training. Training significantly increased both leg and arm $\dot{V}O_2$peak by 13% in the AL group and by 13% and 7%, respectively for the LO group. Resting ejection fraction was increased in the LO group, and was increased during leg exercise in both groups., Stroke index during leg exercise were increased in both groups at submaximal and peak workloads. Peak cardiac index improved to the same extent for both groups. Measures of LV diastolic volume, peak filling and ejection rates were greater after training for the LO vs. AL groups. These

changes, in association with a significantly increased systolic blood pressure at peak exercise levels, suggest that greater LV contractile function improvements occurred in the LO vs. the AL group. In CAD patients with initially low fitness levels, a transfer of fitness to the smaller untrained limbs occurs, and an LV adaptive response is implicated in the response. Walking/jogging produces greater overall training effects than aerobic circuit training, perhaps due to its continuous nature, the recruitment of a large muscle mass, and possibly a larger exercise-induced hypervolemia.

Goodman, L. S., Yang, L., Kelso, B., & Liu, P. (1995). **Cardiovascular effects of varying G-suit pressure and coverage during +1Gz PPB.** *Aviat. Space Environ. Med., (in press).*

Abstract With the continued evolution of Anti-G suits, used to counter the cardiovascular dysfunction arising from +1Gz hypoxia protection positive pressure breathing (PPB), it was hypothesized that full-coverage anti G-suits would offer equal protection while using lower inflation pressures than the traditional 4:1 ratio. Nine experienced subjects were exposed to 2 minutes of 70 mmHG PPB while wearing either the Combat Edge (CE) and Tactical Life Support System (TLSS) garments with the G-suit inflated to 4 x breathing pressure, and the Advanced Tactical Anti G-suit (ATAGS) at 4,3,2, and 1-times the breathing pressure. All subjects were measured with impedance cardiography (IC), and 6 were measured simultaneously with both IC and the Cardioscint™ nuclear probe. IC-estimated stroke volume, relative left ventricular (LV) end-diastolic volume, LV ejection fraction, and peak filling rate were depressed most in the CE and ATAGS 1 conditions (P<.001). Heart rate and mean arterial blood pressure changes were highest and lowest, respectively, using the CE and ATAGS 1 garments (P<.001). There were no differences in these variables between the TLSS, and ATAGS 2-4 conditions. Thus, protection against the PPB-induced fall in LV preload and cardiovascular function may still be adequately afforded by lower G-suit inflation pressures when using full-coverage anti-G suits during PPB intended for high altitude-protection.

Paul, M., & Ackles, K. N. (1995). **Improved G-Tolerance with an Extended-Coverage-Bladder G-suit.** *Aviat. Space Environ. Med., (in press).*

Abstract INTRODUCTION. An extended coverage bladder (ECB) G-suit was evaluated on the DCIEM centrifuge against the current service (Std) G-suit. The ECB G-suit covered approximately 85% of the lower body measuring from the umbilicus and all 5 bladders completely encircled each leg and the lower trunk. The Std G-suit covered approximately 30% of the lower body and it's 5 bladders were located only over the frontal aspect of each leg and the lower trunk. METHODS. Nine highly experienced subjects from the DCIEM A-Team evaluated both suits to determine both relaxed and straining G-tolerances. A standard gradual onset rate (GOR) run was used and suit testing order was counterbalanced across subjects. RESULTS. The test condition G-tolerances are listed as mean ± sem; relaxed tolerances (six subjects) were 5.54 ± 0.37 for the ECB suit and 4.66 ± 0.19 for the Std suit (p=.04, 2-tailed, paired t-test) while straining tolerances (nine subjects for the following three G-suit conditions; ECB with foot bladders, ECB without foot bladders, and Std) were 10.6 ± 0.4, 10.1 ± 0.4, and 9.4 ± 0.5 respectively (p=.01 between all three straining conditions, anova with Scheffé F-test). CONCLUSIONS. The ECB G-suit provides improved G-tolerance for both relaxed and straining exposures. The efficacy of ECB G-suits should be evaluated when used in conjunction with positive pressure breathing. While the ultimate G-suit has yet to be conceived and will no doubt be part of an integrated life support system, ECB G-suits are a step in the right direction in the evolution of life support garmentry.

ENVIRONMENTAL PHYSIOLOGY SECTION

51CA

Physical Performance and Thermal Stress

1986

Bell, D. G., & Jacobs, I. (1986). **Electro-mechanical response times and rate of force development in males and females.** *Med. & Sci. in Sport and Exercise, 18,* 31-36.

Abstract Muscle force development is influenced by both central (pre-motor end plate) and peripheral (post-motor end plate) components. Conflicting results are available concerning gender-related differences in the central component. This study compared males and females with regard to the following electromechanical response variables: total reaction time, pre-motor time, electromechanical delay, and the rate of force development during a maximal voluntary isometric contraction (MVC) of the elbow flexors. Forty-six males and 40 females performed MVCs against a bar attached to a force transducer. Subjects were instructed to attempt to flex the elbow with maximal force as rapidly as possible after perceiving a visual stimulus. Surface electromyographic activity was recorded from the biceps brachii and was sampled simultaneously with the force transducer data at 2 kHz and stored digitally. For data analyses the subjects were separated into four groups based on the force generated during the MVC: weak females, weak males, strong females, and strong males. Neither total reaction time nor pre-motor time was significantly different across groups. The electromechanical delay for both male groups was significantly shorter than for both female groups. Electromechanical delay was weakly, but significantly, correlated with rate of force development and maximum force. During a single MVC the times required to attain 25, 50, 75, and 100% MVC were similar in all groups. The results suggest that at least part of the gender difference in maximum strength may be due to differences in electromechanical response times.

Ducharme, M. B. (1986) ***Energétique de la locomotion et thermorégulation chez les deux morphes de l'écureuil gris.*** M.Sc., Laval University.

Abstract L'Ecureuil gris (*Sciurus carolinensis*) est un Sciuridé arboricole actif tout au long de l'année, même aux latitudes les plus nordiques de son habitat. Dans ces régions où l'hiver impose de très basses températures et une réduction de la disponibilité de la nourriture, les exigences énergétiques de la thermorégulation et de la locomotion peuvent devenir limitantes pour la survie. On s'attend donc à retrouver des adaptations au niveau du métabolisme et de l'isolation thermique favorisant l'économie d'énergie. Les adaptations sont susceptibles d'être différentes chez les morphes gris et noir de l'espèce puisque leur distribution est fonction du climat.

De fait, en hiver, l'Ecureuil gris possède au repos un métabolisme plus économique (surtout aux températures inférieures à 5°C) et un métabolisme de sommet 18% plus élevé qu'en été. L'augmentation du métabolisme de sommet en hiver est due en majeure partie (84%) à l'augmentation de plus de 300% de la capacité de thermogénèse sans frisson. Cette augmentation est attribuable à une hypertrophie des tissus adipeux bruns. Chez le morphe noir acclimaté au froid, l'économie d'énergie au froid est plus marquée que chez le gris. De plus, la capacité de thermogénèse sans frisson est 30% plus élevée chez le noir que chez le gris ce qui s'expliquerait par un contenu en protéines plus élevée chez le noir que chez le gris au niveau des tissus adipeux bruns. Ces avantages de la forme mélanique de l'Ecureuil gris peuvent contribuer à son adaptation apparemment plus grande dans la partie la plus nordique de l'habitat de l'espèce.

L'étude de la locomotion a montré que la dépense d'énergie aérobie lors de la course horizontale sur tapis roulant est une fonction linéaire de la vitesse jusqu'à l'atteinte du métabolisme aérobie maximum à 6 km/h. La valeur minimale du coût de transport global est de 30% supérieure à celle prédite pour un

rongeur type de même masse. En fait, les Sciuridées arboricoles pour lesquels on dispose de mesures présentent un coût de transport supérieur à celui des Sciuridés terricoles de masse correspondante, ce qui laisse croire en des adaptations locomotrices spécifiques au mode de vie.

Lors de la locomotion, les démarches utilisées par l'Ecureuil gris sont la marche (1 - 4 km/h), le trot (4 - 6 km/h), le demi-bond (6 - 8 km/h) et le bond (vitesses supérieures à 9 km/h). L'Ecureuil gris présente certaines adaptations cursoriales typiques permettant d'accroître la longueur de la foulée lors de la course à haute vitesse, ce qui suggère l'existence d'une adaptation à la course sur plan horizontal chez ce Sciurdié arboricole.

Henderson, D. L., & Tikuisis, P. (1986). *Investigation of oxygen pre-breathing at 8000 ft vs. ground level prior to altitude exposure.* (DCIEM 86-C-19). Defence and Civil Institute of Environmental Medicine.

Abstract Denitrogenation of body tissues by breathing 100% oxygen with an oronasal mask at ground level for 30 minutes is routinely used in the Canadian Forces to protect aircrew from decompression sickness (DCS) during altitude exposures above 18,000 feet in the course of Aeromedical Training (AMT). Despite this measure plus limiting the period above 25,000 ft to 20 minutes, a total of 10-12 cases of altitude DCS per year are still being reported by the hypobaric chambers utilized by the CF for AMT. A simple trial was conducted. Results have revealed marked inter-individual differences in the volume of nitrogen eliminated and the mean values do not support a statistically significant difference between oxygen pre-breathing at ground level versus 8,000 ft.

Hoskins, R. W., Melinyshyn, M. J., Romet, T. T., & Goode, R. C. (1986). **Bath rewarming from immersion hypothermia.** *J. Appl. Physiol., 61*(4), 1518-1522.

Abstract Trunk-only bath rewarming has often been recommended over whole-body bath rewarming as a method for the treatment of immersion hypothermia. At present, no report of a direct comparison of the relative merits of these techniques has been made. Authorities in favor of trunk-only bath rewarming base their proposal on the assumption that core temperature afterdrop would be minimized by preventing peripheral vasodilation when the subject's limbs are not immersed in the rewarming bath. In the present study, trunk-only and whole-body bath rewarming are compared by rewarming eight mildly hypothermic male subjects twice, once via each technique. It was concluded that trunk-only rewarming is not superior to whole-body bath rewarming as a therapy for mild-immersion hypothermia, based on the findings that no significant differences existed between the two techniques, either in size or duration of core temperature afterdrop, or in rate of rewarming.

Jacobs, I. (1986). **Blood lactate: implications for training and sports performance.** *Sports Med., 3,* 10-25.

Abstract The blood lactate response to exercise has interested physiologists for over fifty years but has more recently become as routine a variable to measure in many exercise laboratories as is heart rate. This rising popularity is probably due to: a) the ease of sampling and improved accuracy afforded by recently developed micro-assay methods and/or automated lactate analysers, and b) the predictive and evaluative power associated with the lactate response to exercise. Several studies suggest that the strong relationship between exercise performance and lactate-related variables can be attributed

to a reflection by lactate during exercise of not only the functional capacity of the central circulatory apparati to transport oxygen to exercising muscles, but also the peripheral capacity of the musculature to utilize this oxygen. For example, several studies contrast the relationship between $\dot{V}O_2$ max and endurance running performance with that between a lactate variable and the same running performance. In every study, the lactate variable is more high correlated with performance. Similarly, prescribing training intensity as a function of the lactate concentration elicited by the training may prove to be a means of obtaining a more homogeneous adaptation to training in a group of athletes or subjects than is obtained setting intensity as a function of maximal heart rate or % $\dot{V}O_2$ max. A review of the recent literature shows that the lactate response to supramaximal exercise is a sensitive indicator of adaptation to 'sprint training' and is correlated with supramaximal exercise performance. This review also describes the possible applications of lactate measurements to enhance the rate of recovery from high intensity exercise. Although the lactate response to exercise is reproducible under standardized conditions it can be influenced by the site blood sampling, ambient temperature, changes in the body's acid-base balance prior to exercise, prior exercise, dietary manipulations, or pharmacological interpretation.

Jacobs, I., & Pope, J. (1986). **A computerized system for muscle strength evaluation: measurement reproducibility, validity and some normative data.** *National Strength Conditioning Assoc. J., 8,* 28-33.

Abstract This report describes the reproducibility and validity of a computerized muscle strength evaluation system, the Ariel Computer Exercise (ACE) system. The ACE has only recently become commercially available, therefore there are no normative data published for various exercises on the ACE, nor is the measurement accuracy of the apparatus documented. This project attempts to address these aspects. Force measurement was examined three times on each of three separate days (i.e. nine times in total). This was done by comparing the ACE measurement of weights hung on the apparatus to the known calibrated weight Angular velocity was examined by comparing various velocities chosen via ACE software commands to the actual velocity of the ACE lever arm measured with a micro-switch activated timer. Intrasubject reproducibility was evaluated by having six subjects perform maximal contractions on three separate days at various angular velocities. The results indicate that reproducible and valid force measurements and angular velocities are achieved with the ACE provided the system is calibrated according to the manufacturers specifications a least once daily. In addition, average values are presented for various exercises performed by 23 male an 11 female untrained military personnel.

Myles, W. S., & Romet, T. T. (1986). ***Combat Engineer Effectiveness in Sustained Operations.*** (DCIEM 86-R-27). Defence and Civil Institute of Environmental Medicine.

Abstract The effect of sleep deprivation and physical fatigue on self-paced work output was determined in two sustained combat engineer operations. In the first (Ripe Sapper), four subjects from 2 Combat Engineer Regiment went without sleep for 69 hours. During this period they performed only four physically demanding tasks, three of them in the last 24 hours. Continuous recordings of heart rate (HR) indicated that sleep deprivation, in the absence of physical fatigue, had no effect on work intensity and the work/recovery cycle. In the second sustained operation (Longue Journée), six subjects from 5 Combat Engineer Regiment carried out a full schedule of physically demanding tasks during a period of sleep deprivation lasting 47 hours. Some of the tasks were repeated at least once so that the effects of sleep loss and

physical fatigue could be assessed. For the first 14 hours of Longue Journée, the subjects worked at an average HR of 120 bpm which is equivalent to an energy expenditure of 35-40% of maximal oxygen uptake in fit young men. In the remainder of the sustained operation, work intensity declined as the subjects worked for shorter periods and took longer rests. Rating scales confirmed that these changes coincided with the development of physical fatigue. Since sleep deprivation was without effect in Ripe Sapper, the decline in self-paced work output in Longue Journée was attributed to physical fatigue.

Although the evidence is not conclusive and must be confirmed by further research, the results of this study have important implications for those responsible for planning sustained combat engineer operations. Longue Journée demonstrated that the subjects, typical combat engineers, were able to complete all the tasks assigned to them within the allotted 48 hours. Although times to complete individual tasks increased in the later stages, the goal of operating continuously for 48 hours was achieved. The finding that-sleep loss, per se, had no effect on self-paced work output in Ripe Sapper suggests that soldiers who are sleep deprived, but not physically fatigued, can be expected to complete physically demanding tasks in the same time as fresh troops. Moreover, troops who receive at least four hours of dedicated sleep every night should not be considered immune to the effects of sustained operations. If the 20 waking hours are spent in prolonged fatiguing tasks, self-paced work output may still decline.

Romet, T. T., Frim, J., Allen, C., & Shephard, R. J. (1986). **The effects of breathing warm air during cold exposure.** *Arct. Med. Res., 44,* 37-41.

Abstract Heat stores were compared in two groups of 8 young women, exposed respectively to a standard cold environment (–20°C, zero wind speed, 3 clo insulation, intermittent work at 30% of maximum oxygen intake) and similar conditions with the inspired air pre-heated to 15°C. Respiratory heat loss for the two conditions differed by 13.1 Watts. Core temperatures remained constant in both conditions, but all skin temperatures except the exposed forehead were 1 - 2°C colder when the inspired air was not pre-warmed, total body heat loss was thus 281 KJ greater without pre-warming. Ratings of perceived thermal comfort reflected this loss. Pre-warming of inspired air may have value in extending the tolerance of cold stress, particularly in clinical problems such as an angina and exercise-induced bronchospasm.

Romet, T. T., Shephard, R. J., & Frim, J. (1986). **The metabolic cost of exercising in cold air (-20°C).** *Arct. Med. Res., 44,* 29-36.

Abstract The metabolic costs of exercise (uphill treadmill walking alternated with bench stepping at approximately 30% of maximum oxygen intake) were measured in 24 young women exposed to three environments according to a Latin square design. The conditions were warm (WW 15°C, normal clothing), cold (CC -20°C, zero wind speed, 3 clo insulation) and cold with pre-warming of the inspirate to 15°C (CW). The oxygen intake was significantly greater in the cold than in the warm environment, about a half of the increase could be explained by the weight of the arctic clothing, with additional effects from (i) hobbling, (ii) heavy boots and (iii) a reduction of peripheral metabolism. The difference of cost between CC and CW was not statistically significant, but was consistent with the energy loss in warming and humidifying the inspirate. All costs agreed well with Balke/Ware predictions, but were much lower than predictions based on military recruits (Goldman and associates) and the American College of Sports Medicine Guidelines. There is need for further study of walking costs in women, particularly under arctic conditions.

1987

Frim, J. (1987). ***Study of whole body heat exchange with the environment.*** (Contract Report 7942). Defence and Civil Institute of Environmental Medicine.

Abstract The objective of this study was to evaluate whether Heat Flux Transducers (HFTS) attached to the human body provide a true value of sensible heat loss. Twenty-four HFTs were attached to subjects exposed to five climatic conditions in a whole-body human calorimeter. The main conclusions reached are: (1) Calibration of HFTs is mandatory. In the range of heat flows and temperatures encountered in this study a calibration equation of the following form was satisfactory: $Q = mV \cdot (a + b \cdot T)$ where Q = heat flow in W/m^2 and T = HFT temperature. (2) Twenty-four HFTs attached on symmetrical sides of the body (twice the Hardy and DuBois sites) reflect the sensible heat loss of sitting and exercising humans accurately within a few Watts, but with two limitations: (a) The average heat flux from the 24 HFTs is systematically higher than the sensible heat per unit surface area given off by the subject to the calorimeter because the sensible heat detected by the calorimeter leaves the body only through the heat exchanging surface area, which is smaller than the anatomical body surface area used in the calculations. (b) The sensible heat loss predicted with the HFTs is valid as long as there is no appreciable active sweating due to warmer calorimeter temperatures and/or exercise. Under warm conditions the sweat produced under the HFT cannot evaporate and the skin temperature under the HFT rises, resulting in an erroneous increase in heat loss. (3) The minimum number of HFTs required for an estimate of the subject's sensible heat loss is about 12. It is recommended to use the same weighting factors for both the calculation of mean skin temperature and for the average heat flux. (4) The use of a tight-fitting undergarment that covers all HFTs and keeps them properly in place, such as a Unitard ballet costume, is of great assistance in protecting the HFTS, and their wires in particular, against mechanical damage.

Frim, J. (1987). **Fundamentals of thermoregulation.** In J. R. Sutton, C. Houston, & G. Coates (Eds.), *Hypoxia and Cold.* (pp. 29-32). New York: Praeger.

Abstract A discussion of normal physiology as it relates to cold exposure implies a discussion of human thermoregulation. This, in turn, requires an understanding of heat production within the body, of thermal exchange between the body and the environment, and of the regulatory mechanisms used by the body to control these processes.

This chapter provides a brief overview of human thermoregulation encompassing these areas. The emphasis is on the relationships between the various aspects, as opposed to an in-depth look at any one area. This approach is justified by the fact that accidental cold injury of any nature, be it frostbite or hypothermia, is usually not due to a failure of heat production or temperature regulatory mechanism; rather, it is the result of environmental influences calling upon normal physiological mechanisms to function beyond the limits of their capabilities.

Jacobs, I. (1987). ***Nutrition and physical performance in military environments.*** (DCIEM 87-R-53). Defence & Civil Institute of Environmental Medicine.

Abstract This report is a review of research findings concerning nutritional aspects of physical performance with direct relevance to the operational requirements of military personnel.

The body's stores of carbohydrates are limited compared to those of the other energy stores. Unfortunately, it is these limited carbohydrate stores on which muscle is most dependent for fuel as the intensity of

physical exercise increases. When the intramuscular stores of carbohydrates, in the form of glycogen, are depleted subsequent exercise performance is impaired. There is direct evidence that muscle glylcogen stores of military personnel are markedly depleted at the end of combat field trials. The consumption of >450 g of carbohydrate per day should facilitate adequate glycogen resynthesis. There is experimental evidence that adaptation to a calorie-dense, fat-rich, i.e. carbohydrate-poor, diet may be possible although the time course and extent of adaptation must be clarified before such a diet can be applied.

There is no consistent evidence to suggest that the capacity to perform physical exercise would be enhanced by the addition of micronutrients to rations. Further research may be warranted, however, by the findings that amino acids such as l-tryptophan and tyrosine have been demonstrated to enhance cognitive performance under conditions of environmental stress.

Calorie restriction causing body weight loss of up to about 10% will not cause drastic performance impairments if dehydration, ketosis, and hypoglycemia can be avoided. Lightweight dally muons containing 2000 kcal are therefore feasible for units for whom a reduced foodpack weight and volume would be advantageous.

The environmental stress of heat or altitude causes an anorexia which can result in insufficient energy and/or carbohydrate intake to maintain optimal physical performance. Cold environments are usually associated with an increased energy consumption, probably because of the increased caloric cost of working in protective clothing and with specialized equipment. The implications of most environmental stresses are that the relative physiological demands of a given task are increased. In all likelihood the energy cost and the dependence on carbohydrates for that energy are also increased.

Jacobs, I. (Ed.). (1987). ***Human Adaptation to Prolonged Activity.*** Canadian Journal of Sport Sciences.

Abstract This supplementary issue of the Canadian Journal of Sport Sciences contains the proceedings of a satellite symposium held in conjunction with the 1986 triennial congress of the International Union of Physiological Sciences. The challenges to the processes of physiological homeostasis are particularly marked during bouts of sustained exercise, and it is for this reason that the focus of the symposium was adaptations to prolonged activity in normal and hostile environments. The proceedings consists of reviews of the following factors with reference to mechanisms by which they limit the capacity to perform prolonged exercise: neuromuscular factors, the respiratory system, blood flow limitations, hormonal control and enzyme regulation of prolonged effort, and environmental limitations.

Jacobs, I. (1987). **Influence of carbohydrate stores on maximal human power output.** In D. MacLeod, R. Maughan, T. Reilly, & C. Williams (Eds.), *Exercise - Benefits, Limits and Adaptations,*. (pp. 104-115). London: E. & F.N. Spon.

Abstract There is a well established relationship between endurance exercise performance and muscle glycogen availability. This paper describes the result of recent studies which examined the effects of skeletal muscle glycogen depletion on performance of a one minute maximal intensity muscle fatigue test (MFT). When acute glycogen depletion or both main muscle fibre types was induced by exercise, subsequent muscle strength and power during the MFT were impaired. Subjects with muscle rich in FT fibers demonstrated a greater impairment than those rich in ST fibers. If exercise-induced glycogen depletion was limited to the ST muscle fibers, no significant impairment of muscle force was observed, but the muscle was more susceptible to fatigue during repeated maximal contractions. If muscle glycogen levels were very low prior to exercise, im-

pairments of force production were accompanied by significantly reduced muscle lactate accumulation during the MFT, suggesting that glycogenolytic flux was reduced. Although muscle weakness observed after prolonged exercise may be a function of the exercise used to induce glycogen depletion, the weakness is greater when glycogen levels in the exercising muscles are low.

Jacobs, I., Bell, D. G., Pope, J., & Lee, S. W. (1987). **Effects of hydraulic resistance circuit training on physical fitness components of potential relevance to +Gz tolerance.** *Aviat. Space Environ. Med., 58,* 754-760.

Abstract Recent studies carried out in the United States and Sweden have demonstrated that strength training can improve +Gz acceleration tolerance. Based on these findings, the Canadian Forces have Introduced a training program for aircrew of high performance aircraft. This report describes the changes In physical fitness components considered relevant to +Gz tolerance after 42 weeks of training with this program. Prior to beginning training, 45 military personnel were tested, but only 20 completed a minimum of 24 training sessions. The following variables were measured in these 20 subjects before and after training: maximal strength of several large muscle groups during isokinetic contractions, maximal aerobic power and an endurance fitness index, maximal anaerobic power, anthropometric characteristics, and maximal expiratory pressure generated during exhalation. Training involved hydraulic resistance circuit training 2-4 times/week. The circuit consisted of 3 consecutive sets at each of 8 stations using Hydra-Gym equipment. The exercise:rest ratio was 20:40 s for the initial 4 training weeks and was then changed to 30:50. After training the changes in anthropometric measurements suggested that lean body mass was increased. Small, but significant increases were also measured in muscle strength during bench press, biceps curls, squats, knee extension, and knee flexion. Neither maximal anaerobic power (i.e. muscular endurance) nor maximal expiratory pressure were changed after the training. Indices of endurance fitness were also increased in the present study. The relatively small increases in strength are probably due to the design of the exercise:rest ratio which resulted in improved strength and aerobic fitness. Other studies suggest that combined strength and endurance training reduces the rate of strength increase usually found when engaging in only strength training. Therefore, it is recommended that if the main objective of physical training for aircrew is to enhance fitness components relevant to +Gz tolerance, then the available training time should be used to concentrate on increasing muscle strength.

Jacobs, I., Esbjörnsson, E., Sylvén, C., Holm, I., & Jansson, E. (1987). **Sprint training effects on muscle myoglobin, enzymes, fiber types and blood lactate.** *Med. Sci. Sports Exercise., 19,* 368-374.

Abstract The purpose of this study was to determine if changes in intra-muscular myoglobin concentration accompany histochemical and enzymatic adaptations to supra-maximal exercise training. Subjects were assigned to either a training group (N = 11), who trained 2 to 3 times weekly for 6 wk, or a control group (N = 6). Training progressed from two 15-s and two 30-s "all-out" sprints on a cycle ergometer during week 1 to six 15-s and six 30-s bouts per session during week 6. The Wingate test was performed before and after the 6 wk, but performance variables were not changed in either group. In the training group, peak lactate after the Wingate test was significantly higher after training. No significant changes in enzyme activities, myoglobin concentration, or fiber-type frequency were observed in the control group. In contrast, in the training group, the percent fast twitch oxidative fibers increased, myoglobin decreased, and both citrate synthase and phosphofructokinase ac-

tivities increased ($P < 0.05$). The results suggest that muscle myoglobin concentration is not increased by 6 wk of supra-maximal exercise training and that such training induces cellular adaptations without accompanying performance changes. Alternatively, the Wingate test is not a sensitive test of adaptations to the training.

Knowles, D., Buick, F., Robbins, G., Kuhlman, W., & Weiss, R. (1987). **Physiological implications of wearing CCBA for NBC protection.** In *International Task Force-3.Report No. ITF-3.* (pp. 210-218). US/UK/CAN MOU on CB Defence. (Restricted).

Abstract (Restricted Report)

Livingstone, S., Nolan, R., Frim, J., Reed, L., & Limmer, R. (1987). **A thermographic study of the effect of body composition and ambient temperature on the accuracy of mean skin temperature calculations.** *Eur. J. Appl. Physiol., 56,* 120-125.

Abstract The problem associated with using measurements from a small number of sites to determine mean skin temperature was investigated by studying variations in distributions of skin temperatures of the bare torsos of humans exposed to ambient temperatures of 18, 23, and 28°C. Following a 60 minute equilibration period the temperatures of four regions (chest, abdomen, upper back, and lower back) were measured using both thermistors and an infra-red thermographic system. Regions of the torso usually represented by a single temperature exhibited significant point-to-point temperature variations especially in chilled subjects. Also an earlier finding was confirmed: in that larger variations in skin temperature distributions occur as body fat content increases. Caution must therefore be used in applying the concept of a mean skin temperature derived from a few select sites, especially with nude subjects who are chilled or have a high body fat content.

McLellan, T. M. (1987). **The anaerobic threshold: concept and controversy.** *Aust. J. Sci. Med. Sport., 19,* 3-8.

Abstract The purposes of this review are twofold. First, the importance of understanding the influence of a 'fast' (power output increments every minute) or 'slow' (increments every four minutes) incremental test on the changes in gas exchange and acid-base measures that are used to identify the anaerobic threshold is stressed. Second, the controversy that has evolved concerning the concept of the anaerobic threshold is discussed. These areas of controversy include, terminology, the proposed cause and effect relationship between the ventilatory and plasma lactate response, and intra- and interinvestigator variability in the determination of individual anaerobic threshold values. Hopefully, this review will assist in the standardisation of the methods used to identify the anaerobic threshold and reduce the controversy that has developed within this area of research.

Paterson, D. H., McLellan, T. M., Stella, R. S., & Cunningham, D. A. (1987). **Longitudinal study of ventilation threshold and maximal O2 uptake in athletic boys.** *J. Appl. Physiol., 62,* 2051-2057.

Abstract Ventilation threshold (VET) and peak O_2, uptake ($\dot{V}O_2$ max) were determined annually from ages 11 to 15 yr in 18 athletic boys. The treadmill protocol consisted of a constant-run speed with grade increments every second minute. Ventilation, $\dot{V}O_2$, and CO_2 production were measured using online open-circuit spirometry. Coefficients of variation for determination of

$\dot{V}O_2$ max and VET were 3.4 and 5.6%, respectively. $\dot{V}O_2$ max increased across age 11-15 yr, from 60.8 to 68.0 ml·kg^{-1}·min^{-1}. VET at 11 yr was 34.4 and at 15 yr 41.9 ml·kg^{-1}. min^{-1}, thus increasing from 56 to 62% of $\dot{V}O_2$ max. Previous studies of children have shown a decline of VET relative to $\dot{V}O_2$ max across age; however, in the present study the increase may have been due to the training of the boys in competitive athletics. However, the trained youth did not achieve the high relative threshold of trained adults. Across age, both $\dot{V}O_2$ max and VET scaled to weight to the power 1 (in a log-log transformation). The increase in $\dot{V}O_2$ max (1/min) showed greatest increments corresponding to gains in size (a growth curve), whereas increases of VET were consistent year to year. Thus VET was altered independently of $\dot{V}O_2$ max. Factors other than size (and presumably muscle mass) such as the maturation of an enzymatic profile of fast glycolytic fibers might have an important influence on the threshold during youth.

Romet, T. T. (1987). ***A comparison of rectal, auditory canal and esophageal temperature sites during rewarming from mild hypothermia.*** (DCIEM 87-RR-18). Defence and Civil Institute of Environmental Medicine.

Abstract Eight healthy male volunteers (aged 21 to 32 yrs) were cooled in 22°C water on three occasions and immediately rewarmed once each by inhalation of 45°C humidified air by immersion in 40°C water and by spontaneous shivering. Three measures of deep body temperature, rectal, auditory canal, and esophageal were followed during the cooling and the subsequent rewarming. There were no differences in the measured rate of cooling between the three core temperature sites. Rewarming for each temperature site was analyzed by the magnitude of afterdrop by the duration of afterdrop and by the rate of rewarming. Regardless of which rewarming technique was studies, temperatures measured at the esophageal site always-showed the least after drop in both magnitude and duration as compared to the rectal and auditory canal sites. While there were no differences in the rewarming rates calculated for each of the three sites during inhalation or spontaneous rewarming, auditory canal and esophageal sites were observed to have significantly greater rewarming rates than rectal during rapid rewarming in 40°C water. The results show that the esophageal site is the most sensitive to changes in deep body temperature during rewarming and would be the method of choice if it were simpler to measure. However, during rewarming in which there is a slow rate of rewarming as in spontaneous or inhalation rewarming, all three sites appear to be equally as effective in reflecting rewarming rates.

Romet, T. T. (1987). ***A Comparison of Inhalation, Spontaneous and Rapid External Rewarming of Mildly Hypothermic Subjects.*** (DCIEM 87-RR-17). Defence and Civil Institute of Environmental Medicine.

Abstract Eight healthy males were each cooled on four occasions and then rewarmed by one of three rewarming procedures: by inhalation of warmed and humidified air once at 40°C and once at 45°C, by immersion in 40°C water and by spontaneous shivering. Using rectal temperature as the measure of core temperature, the results showed that rapid external rewarming in 40°C water produced the quickest rates of rewarming along with the smallest magnitude and duration of afterdrop. There were no significant differences in rewarming rate or afterdrop between inhalation rewarming and spontaneously rewarming (shivering). Inhalation rewarming led to a depressed metabolic rate as compared to spontaneous rewarming which was not compensated for by the heat provided through the respiratory

tract. It is concluded that for mildly cooled subjects, the most efficient procedure of rewarming is by rapid external rewarming in 40°C water.

Romet, T. T., & Frim, J. (1987). **Physiological responses to firefighting activities.** *Eur. J. Appl. Physiol., 56,* 633-638.

Abstract Eight professional fire fighters participated in six fire fighting scenarios at a training facility. Data on heart rate (HR), rectal temperature (Tre), and skin temperatures at the chest and thigh were collected using a portable data acquisition system. Average HR ranged from 122 to 151 beats · min^{-1} during the six scenarios. Detailed analyses indicated that HR and Tre, increases are related to both the physical and environmental stresses of the various activities carried out. The most demanding activity, that of building search and victim rescue, resulted in an average HR of 153 beats · min^{-1} and Tre rise of 1.3°C, while the least demanding activity, that of the crew captain who directs the fire fighting, resulted in an average HR of only 122 beats · min^{-1} and a Tre rise of only 0.3°C. This study shows that fire fighting is strenuous work for those directly entering a building and performing related duties but that the physical demands of other activities are considerably less. The results further suggest that heat strain injuries in fire fighters could perhaps be reduced by rotating duties frequently with other crew members performing less stressful work.

Tikuisis, P., Gonzalez, R. R., & Pandolf, K. B. (1987). ***Human thermoregulatory model for whole body immersion in water at 20 and 28° C.*** (USARIEM T23-87). US Army Research Institute of Environmental Medicine.

Abstract The mathematical models of thermoregulation of Stolwijk and Hardy and Montgomery were used to develop a model suitable for the simulation of human physiological responses to cold-water immersion. Data were obtained from experiments where thirteen healthy male volunteers were totally immersed under resting and nude conditions for 1 h in water temperatures of 20 and 28°C. Mean measured rectal temperature (T_{re}) fell by about 0.9 and 0.5°C in 20 and 28°C water for all subjects, yet mean measured metabolic rate (M) rose by about 275 and 90 W for the low body fat group (n=7) and 195 and 45 W for the moderate body fat group (n=6). To predict the observed T_{re} and M values, the present model a) included thermal inputs for shivering from the skin independent of their inclusion with the central temperature to account for the observed initial rapid rise in M, b) determined a thermally neutral body temperature profile such that the measured and predicted initial values of T_{re} and M were matched, c) confined the initial shivering to the trunk region to avoid an overly large predicted initial rate of rectal cooling, and d) calculated the steady-state convective heat loss by assuming a zero heat storage in the skin compartment.

1988

Bell, D. G., Jacobs, I., Sale, D. G., & MacDougall, J. D. (1988). ***The effect of concurrent strength and endurance training on electromechanical delay, maximum voluntary contraction, and rate of force development.*** (DCIEM 88-RR-33). Defence & Civil Institute of Environmental Medicine.

Abstract This study compared the effect of strength and endurance training and their combination on electromechanical delays (EMD), rate of force development (RFD) and maximum voluntary isometric contraction force (MVC) of the knee extensors in male and female subjects. The seven male and six female subjects were separated into a strength trained group (SG), 3 males and 3

females, and an endurance group (EG), 4 males and 3 females. The SG performed strength training solely with one leg and combined strength and endurance training with the other leg. The EG performed endurance training solely in one leg and combined strength and endurance training in the other leg. Strength training consisted of one legged work on a leg press weight machine. Endurance training consisted of one legged cycling on a cycle ergometer. EMD values were derived from electromyographic activity (EMG) recorded from the vastus lateralis muscle during MVC. MVC responses were made to a light stimulus and were performed with each leg, pre, mid and post training. MVC force was measured with a force transducer. Rate of force development (RFD) was determined from the MVC/time curves using computer software. The EMG, MVC/time curves and light signal data were simultaneously recorded on FM tape and later sampled at 2kHz and stored digitally. The results showed that EMD was significantly reduced only in the SG females. This change had occurred by mid evaluation. Post training data showed that the EMD values for the SG females had increased and were not different from initial levels. EMD times for the males were significantly shorter than the females. MVC for females significantly increased (approximately 40%) and were similar in both legs. The MVC of the males in EG showed significant and similar increases in both legs (approximately 20%). The MVC of the males in the SG showed no significant gains in either leg. Males were significantly stronger than females. Training did not increase RFD and RFD was greater in the males than the females. The data suggest that the increase in MVC that occurred with training in this study was not related to shorter EMD times.

Bell, D. G., Kavanagh, M. F., & Jacobs, I. (1988). ***Blood lactate response to the CF EXPRES test.*** (DCIEM 88-R-50). Defence & Civil Institute of Environmental Medicine.

Abstract This study evaluated the blood lactate (LA) response to stepping exercise, specifically the Canadian Aerobic Fitness Test (CAFT). It also compared the ability of lactate and heart rate at a given stage of the step test to predict maximal aerobic power ($\dot{V}O_2$ max). Sixty-nine male and female CF personnel between the ages of 30 and 50 years participated in this study. The LA concentration after each stage of the CAFT was measured in all subjects by sampling blood from the finger-tip. Eighteen of these male subjects also had their $\dot{V}O_2$ max measured directly during a maximal treadmill run. The analysis of the data showed that the step test significantly raised LA in both the male and female subjects ($p<.05$). When the LA and heart rate measures at stage four of the step test was compared for their ability to predict treadmill $\dot{V}O_2$ max, LA was the better predictor. The correlation between lactate and $\dot{V}O_2$ max was -0.33, while between heart rate and $\dot{V}O_2$ max it was –0.02. These preliminary results suggest that lactate measured during the CAFT is at least as good and perhaps a better predictor of $\dot{V}O_2$ max than heart rate.

Ducharme, M. B., & Frim, J. (1988). **A multicouple probe for temperature gradient measurements in biological materials.** *J. Appl. Physiol., 65,* 2337-2342.

Abstract An easy-to-make, sensitive, thin, flexible, multisensor probe for in vivo tissue temperature profile measurement is described. It is essentially a multijunction thermocouple (i.e., a multicouple) of type-T composition. Enamel-insulated copper wires (38 gauge) were soldered 5 mm apart to one common uninsulated constantant wire (36 gauge) and introduced into a polyethylene tube sealed at one end. The total outside di-

ameter of the multicouple probe is <1 mm, and the maximum number of junctions using the specified wire sizes is ~16. This design permits the instantaneous measurement of a tissue temperature profile at 5 mm intervals over a distance of ~8 cm. An extensive calibration for the thermal conductivity effect (k effect) along the multicouple wires by means of a limb model is presented. The results show that the temperature readings of the individual junctions are significantly affected by the k effect when a thermal gradient exists along the multicouple, as is usually the case during tissue temperature measurements. However, calibration of the multicouple for the k effect yields a measurement accuracy of ±0.1°C under a wide range of gradients. This probe can be implanted in tissues to measure thermal gradients under different physiological conditions.

Frim, J., & Romet, T. T. (1988). *Role of the moisture/vapour barrier in the retention of metabolic heat during firefighting.* (DCIEM 88-RR-40). Defence and Civil Institute of Environmental Medicine.

Abstract The relationship between metabolic heat build-up and the vapour permeability of the barrier layer in fire fighter turnout clothing was examined under a variety of conditions. Laboratory exercise tasks were used to simulate the work of fire fighters performing under three different environmental conditions, cold, hot and extended very hot conditions. The laboratory studies were followed by a field trial in which true fire fighting activities were performed. The clothing elements examined included three outer shells, five moisture/vapour barrier configurations, and two thermal liners. Ten parameters indicative of thermal physiological strain were monitored in eight professional fire fighters to assess the role of the barrier in the retention of metabolic heat.

The results showed that the moisture/vapour barrier material/configuration was the dominant factor in determining thermal physiological strain, with the shell and liner playing very minor roles. Differences in strain as a function of barrier were discernible even under low to moderate stress, but became more pronounced with higher ambient temperatures and longer work periods. The laboratory results were clearly substantiated during the field trial.

It is concluded that a full vapour barrier of a material such as neoprene leads to significantly higher thermal physiological strain than a vapour permeable water barrier of a material such as Gore-tex®. Partial coverage barriers of either material provide even greater reduction in strain, and omission of the barrier entirely is best from a physiological perspective. The best fire fighter turnout clothing will be a compromise between the requirement to protect against external hazards and the need to dissipate metabolically generated heat.

Heslegrave, R. J., Frim, J., Bossi, L., & Popplow, J. R. (1988). *The psychological, physiological and performance impact of sustained NBC operations on fighter pilots.* (DCIEM 90-RR-08). Defence and Civil Institute of Environmental Medicine.

Abstract The impact of sustained NBC operations on the capability of CF-18 pilots was investigated during two weeks of flight trials where pilots flew operational missions in full Individual Protective Equipment (IPE) accompanied by a safety pilot in normal flight clothing. During each week of the trial 3 pilots flew 3 missions per day for two days followed by a single mission on the third day and remained encapsulated in the IPE for up to 8 hours on each multi-mission day. Over the two weeks 42 successful missions were completed in full IPE.

The major finding of the study was that CF-18 pilots in full IPE retained their operational effectiveness and showed little objective evidence of degraded efficiency or safety. Both the objective flight perfor-

mance information and objective cognitive tests failed to indicate significant impairment. However, IPE pilots reported increased levels of fatigue, deterioration in mood, and subjectively reported flight performance impairment on some missions. Physiologically IPE pilots showed greater increases in core temperature than safety pilots but these increases were not as severe as expected even though environmental temperatures were higher than seasonal (summer) norms. When pilots were given an opportunity to rest between missions while remaining encapsulated, their elevated core temperatures dropped substantially. IPE pilots also showed higher heart rates, reduced heart rate variability and reductions in respiratory sinus arrhythmia indicating that they were under somewhat more physiological stress than the safety pilots. Finally, IPE pilots appeared to require better sleep than their safety pilot counterparts to recover from the sustained NBC operation.

The results suggest that under conditions similar to those of this trial, thermal stress under operational conditions can be minimized and pilots could operate under sustained NBC operations effectively and safely. As a caveat to this conclusion, however, there was evidence of cumulative fatigue in these pilots after two days and care must be exercised to minimize factors that would add to the fatigue of pilots and maximize factors that promote recovery from fatigue (rest and sleep).

Heslegrave, R. J., Frim, J., Bossi, L., & Popplow, J. R. (1988). ***Sustained CF188 NBC operations: expectations of performance degradation and flight simulator results.*** (DCIEM 88-RR-10). Defence and Civil Institute of Environmental Medicine.

Abstract As part of Canada's commitment to operations in the European theatre, Canadian CF188 aircrew are expected to operate under sustained nuclear, biological, and chemical (NBC) conditions. In support of this commitment, a three-phase research programme is underway to assess behavioural and physiological changes during sustained NBC operations. The aims of the programme are: (1) to determine the effects of sustained NBC operations on performance; (2) to establish personal cooling requirements; and (3) to provide a guide for commanders on the changes in aircrew performance under sustained NBC conditions. This report summarizes the findings from the first two phases of the project: In Phase I the expectations of performance decrements during sustained and NBC operations were assessed by pilots while in Phase II a simulated sustained NBC operation was carried out using a flight simulator. This latter phase also assessed the feasibility of the experimental protocol and measurement techniques to be used in the final phase of the project where simulator flights will be replaced by aircraft missions.

The results of Phase I confirmed that normal CF188 flights lead to increased fatigue levels. In addition, pilots reported that they expect their performance to be markedly impaired by both sustained and NBC operations. The results of Phase II showed that the simulated sustained NBC operation did not impact greatly on the pilots. The behavioural results indicated that the three-flight per day schedule on successive days did not produce significant decrements in cognitive nor simulator performance. Subjects did, however, report increased fatigue and deterioration in their mood. Also, some aspects of their sleep suggested that there was an enhanced need for recovery during sleep following this regimen. Since ambient temperatures were cool, subjects were not thermally stressed in their individual protective ensemble (IPE) during Phase II. Body temperatures and heart rate increased somewhat during the simulator missions and then decreased between simulator missions while subjects rested in IPE. From the first two phases of the project it was concluded: (1) that pilots anticipate significant performance impairment during sustained NBC operations; (2) that the collection of actual

mission data using a multi-mission multi-day protocol is technically and operationally feasible; and (3) that the behavioural or physiological data suggest that wearing IPE during simulator missions for extended periods under cool conditions does not lead to significant performance impairment. These conclusions demonstrate the necessity and feasibility of assessing sustained NBC operations under operational conditions.

Jacobs, I. (1988). **Nutrition for the elite footballer.** In T. Reilly, A. Lees, K. Davids, & W. J. Murphy (Eds.), *Science and Football.* (pp. 23-32). London: E. & F.N. Spon.

Abstract This paper was an invited presentation at the First World Congress of Science and Football held in Liverpool, UK, in April 1987. The purpose of the paper was to present the football practitioner with the results of nutrition studies which, if properly applied, should enhance the potential for players to perform at their physical optimum. The majority of the presentation centered around the consumption of carbohydrate since it is the only macronutrient the availability of which has been shown to be associated with enhanced or impaired exercise performance. Competitive football demands exercise at a relatively high intensity for a prolonged duration as well as maximal intensity, sprint-like exercise performed intermittently throughout a match. The rate at which the energy required to meet these demands must be supplied, dictates that the musculature is highly dependent on its stores of glycogen. Exhaustion of these stores impairs the athlete's ability to perform up to his/her potential. This paper attempted to enhance awareness of the quantity of carbohydrates one must consume to ensure that sufficient muscle glycogen stores will be available at the beginning of a match so that skill and physical fitness, not fuel availability, will decide the winner.

Jacobs, I., Bell, D., & Pope., J. (1988). **Comparison of isokinetic and isoinertial lifting tests as predictors of lifting capacity.** *Eur. J. Appl. Physiol., 57,* 146-153.

Abstract This study compared the relationship between isokinetic lifting test (ILT) performance and a maximal operational lifting test (OLT) with that between an isoinertial progressive lifting test (PLT) and OLT. Fifty subjects performed the ILT, PLT and OLT after familiarization trials. OLT was defined as the weight of the heaviest crate that could be lifted to 1.34 m with a progressive, incremental test. ILT performance was the force generated during a single maximal simulated lift on an isokinetic dynamometer. PLT performance was the maximal weight lifted to 1.52 m with a progressive, incremental protocol on a weight stack. OLT was highly correlated with ILT (r=0.96) and PLT (r=0.97); the standard error was similar for both linear regression equations. The results demonstrate that a single maximal voluntary lift on an isokinetic dynamometer is as good a predictor of OLT as in the PLT presently used in military recruit centers.

Kavanagh, M. F., & Jacobs, I. (1988). **Breath-by-breath oxygen consumption during performance of the Wingate test.** *Can. J. Sport Sci., 13,* 91-93.

Abstract The aerobic contribution to the Wingate Anaerobic Power Test (WAnT) was evaluated by measuring breath-by-breath oxygen consumption ($\dot{V}O_2$) in five male subjects. Assuming an optimal mechanical efficiency, net $\dot{V}O_2$, during the WAnT could accountfor about 18.5% of the work performed.

Leatt, P. B., & Jacobs, I. (1988). **Effect of a liquid glucose supplement on muscle glycogen**

resynthesis after a soccer match. In T. Reilly, K. A. Lees, Davids, & W. J. Murphy (Eds.), *Science and Football.* (pp. 42-47). London: E. & F.N. Spon.

Abstract This paper was presented at the First World Congress of Science and Football in Liverpool, UK, in April 1987. An adequate intake of dietary carbohydrate is necessary to permit glycogen resynthesis following exercise. The present study employed a glucose polymer supplement to raise the carbohydrate intake of some of the subjects. It was hypothesized that the subjects who consumed the glucose solution would, by virtue of their higher carbohydrate intake, have a greater muscle glycogen resynthesis than a control group who ingested a placebo. Subjects were recruited from the Canadian National Youth Soccer Team. After a competitive soccer match, a biopsy was taken from the thigh musculature and they were divided into two groups, balanced for playing position. One group was given 2.5 L of a 7% glucose polymer solution and the other group was given an equal volume of water sweetened with an artificial sweetener. The subjects were told to consume the drinks together with their normal uncontrolled diet during the following 24 h, after which they returned for another biopsy of the thigh. There were no significant differences in muscle glycogen concentration between the two groups either after the soccer match or 19 h later. In conclusion, a glucose polymer supplement did not increase the rate of muscle glycogen resynthesis following soccer match-play, over and above that obtained from normal, uncontrolled nutritional intake.

Martineau, L., & Jacobs, I. (1988). **Muscle glycogen utilization during shivering thermogenesis in humans.** *J. Appl. Physiol., 65,* 2046-2050.

Abstract The purpose of the present study was to clarify the importance of skeletal muscle glycogen as a fuel for shivering thermogenesis in humans during cold-water immersion. Fourteen seminude subjects were immersed to the shoulders in 18°C water for 90 min or until rectal temperature (T_{re}) decreased to 35.5°C. Biopsies from the vastus lateralis muscle and venous blood samples were obtained before and immediately after the immersion. Metabolic rate increased during the immersion to 3.5 ± 0.3 (SE) times resting values, whereas T_{re} decreased by 0.9°C to 35.8°C at the end of the immersion. Intramuscular glycogen concentration in the vastus lateralis decreased from 410 ± 15 to 332 ± 18 mmol glucose/kg dry muscle, with each subject showing a decrease ($P < 0.001$). Plasma volume decreased ($P < 0.001$) markedly during the immersion (-24 ± 1 %). After correcting for this decrease, blood lactate and plasma glycerol levels increased by 60 ($P < 0.05$) and 38% ($P < 0.01$), respectively, whereas plasma glucose levels were reduced by 20% after the immersion ($P < 0.001$). The mean expiratory exchange ratio showed a biphasic pattern, increasing initially during the first 30 min of the immersion from 0.80 ± 0.06 to 0.85 ± 0.05 ($P < 0.01$) and decreasing thereafter toward basal values. The results demonstrate clearly that intramuscular glycogen reserves are used as a metabolic substrate to fuel intensive thermogenic shivering activity of human skeletal muscle.

McLellan, T., Jacobs, I., & Lewis, W. (1988). **Acute altitude exposure and altered acid-base states. Part I: Effects on the exercise ventilation and blood lactate response.** *Eur. J. Appl. Physiol, 57,* 435-444.

Abstract This study examined the influence of acute altitude (AL) exposure alone or in combination with metabolic acid-base manipulations on the exercise ventilatory and blood lactate responses. Four subjects performed a 4 min, 30 W incremental test to exhaustion at ground level (GL) and a 4 min, 20 W incremental test during three acute exposures to a simulated altitude of 4200 m; (i) normal (NAL), (ii) following 0.2 $g \cdot kg^{-1}$ ingestion of sodium bicarbonate (BAL), and

(iii) following 0.5 g·day^{-1} ingestion of acetazolamide for 2 days prior to exposure (AAL). $V_E \bullet \dot{V}O_2^{-1}$ increased progressively throughout the incremental tests at AL and the minimum value was not related to a change in the blood lactate response. In contrast, the $V_E \cdot V_{CO2}^{-1}$, decreased initially to reach a minimum value at the same power output for each altitude trial and was related to a lactate threshold defined by a log-log transformation (r = 0.78). This transformation of the blood lactate data was not influenced by the altered acid-base states. The relative exercise intensity corresponding to both a Δ lactate of 1 mM and an absolute lactate of 4 mM was significantly increased during the AAL (79.9 ± 12.9 and 93.9 ± 13.7% $\dot{V}O_2$ max, respectively) compared with NAL (59.1 ± 5.5 and 78.0 ± 5.8% $\dot{V}O_2$ max, respectively). These data suggest that strong relationships exist between the ventilatory and blood lactate response during AL exposure and altered acid-base states. Further, it is concluded that, unless the acid-base status is known, the use of an absolute or Δ lactate value to compare submaximal exercise should be interpreted with caution.

McLellan, T. M., Jacobs, I., & Lewis, W. (1988). **Acute altitude exposure and altered acid-base states. Part II: Effects on exercise performance and muscle and blood lactate.** *Eur. J. Appl. Physiol., 57,* 445-451.

Abstract This study examined the influence of the respiratory alkalosis of acute altitude (AL) exposure alone or in combination with metabolic acid-base manipulations on exercise performance and muscle and blood lactate accumulation. Four subjects exercised for 10 min at 50% and 75% and to exhaustion at 90% of ground level (GL) $\dot{V}O_2$ max, and at the same relative exercise intensities during three exposures to a simulated altitude of 4200 m; (i) normal (NAL), (ii) following 0.2 g · kg^{-1} ingestion of sodium bicarbonate (BAL), and (iii) following 0.5 g · kg^{-1} ingestion of acetazolamide for 2 days prior to exposure (AAL). Muscle and blood lactate values were similar throughout exercise for GL and NAL. Although muscle lactates were similar among AL conditions blood lactate was reduced for AAL and increased following exhaustive exercise for BAL compared with NAL. Time to exhaustion at 90% $\dot{V}O_2$ max was increased for NAL (10.4 ± 1.6 min) compared with GL (7.1 ± 0.2 min). Performance time was decreased for AAL (6.3 ± 2.8 min) compared with NAL and BAL (12.4 ± 4.2 min). These data suggest that the induced respiratory alkalosis of acute AL exposure may enhance exercise performance at high relative intensities. In contrast, the ingestion of acetazolamide before AL exposure would have detrimental effects on performance. The mechanism responsible for these changes may relate to the possible influence of altered extracellular acid-base states on intracellular hydrogen ion accumulation and lactate release.

Romet, T. T. (1988). **Mechanism of after drop after cold water immersion.** *J. Applied Physiol, 65(4),* 1535-38.

Abstract It was hypothesized that if afterdrop is a purely conductive phenomena, the afterdrop during rewarming should proceed initially at a rate equal to the rate of cooling. Eight male subjects were cooled on three occasions in 22°C water and rewarmed once by each of three procedures, spontaneously shivering, inhalation of heated (45°C) and humidified air, and immersion up to the neck in 40°C water. Deep body temperature was recorded at three sites, esophagus auditory canal and rectum. During spontaneous and inhalation rewarming, there were no significant differences between the cooling (final 30 min) and afterdrop (initial 10 min) rates as calculated for each deep body temperature site, thus supporting the hypothesis. During rapid rewarding, the afterdrop rate was significantly greater than

during the preceding cooling suggesting a convective component contributing to the increased rate of fall. The rapid reversal of the afterdrop also indicates that a convective component contributes to the rewarming process as well.

Romet, T. T., & Hoskins, R. W. (1988). **Temperature and metabolic responses to inhalation and bath rewarming protocols.** *Aviat. Space Environ. Med., 59,* 630-34.

Abstract Rewarming of mildly hypothermic subjects was compared using three different techniques that have been suggested for use in field situations. Eight subjects were cooled for up to one hour, on four occasions, in a filled whole body water calorimeter controlled at 22°C. Following cooling, rewarming was initiated by one of four procedures: inhalation of warmed and humidified, air at 40°C or 45°C, immersion in 40°C water, or spontaneously by shivering. Deep body temperature was recorded simultaneously at three different sites, rectal, esophageal and auditory canal. Skin temperatures were recorded from four sites: chest, forearm, thigh and calf. Results showed that rapid external rewarming in 40°C water produced the quickest rate of rewarming and smallest magnitude and duration of afterdrop. Regardless of which rewarming protocol was followed, the esophageal site always showed the smallest afterdrop. Although there were no differences in the rewarming rates calculated for each of the three core temperature sites during inhalation and spontaneous rewarming, both auditory canal and esophageal sites rose significantly quicker than rectal during the rapid rewarming in 40°C water. Inhalation rewarming led to a depressed metabolic rate as compared to spontaneous rewarming which was not compensated for by the heat provided through the respiratory tract. It was concluded that for mildly hypothermic subjects, rapid rewarming in 40°C water was the most efficient procedure and that esophageal temperature, the closest approximation of aortic blood or cardiac temperature, is the most sensitive to change during rewarming by any procedure. Inhalation rewarming may be suitable as a passive rewarming technique by eliminating respiratory heat loss, allowing rewarming to occur and while preserving metabolic stores.

Smith, D. J., Edwards, J. S. A., & Jacobs, I. (1988). ***Nutrient requirements and recommendations for military personnel.*** (INM 25/88). Royal Navy Institute of Naval Medicine.

Abstract Nutrient requirements, including water, and Recommended Dietary Intakes for military personnel are by their very nature an imprecise calculation especially when applied to individuals. This has resulted in recommendations being made, not for individuals, but for particular subgroups of the population. Using data available from civilian sources and from a range of NATO nations, recommendations on which dietary management should be based are presented. The Recommended Dietary Intakes of nutrients are summarized. They are based on information currently available. Modifications will need to be made as additional research data becomes available. It is recommended that they be adopted by the Armed Forces for the planning and monitoring of military diets both in and out of barracks. Using nutritional strategies to enhance military performance is a relatively new concept. Dedicated research in this area will be required if nutritional status is to contribute towards the health and performance of military personnel.

Symons, J. D., Bell, D. G., Pope, J., VanHelder, T., & Myles, W. S. (1988).

Electro-mechanical response times and muscle strength after sleep deprivation. *Can. Journal of Sport Sciences., 13,* 225-230.

Abstract This study examined the effect of 60 h of sleep deprivation (SD) on electromechanical response times (EMRT), maximal voluntary isometric contraction (MVC), rate of force development (RFD), and times required to reach various percentages of MVC, during a maximal voluntary isometric contraction of both the forearm flexors and leg extensors. Eleven male subjects were either sleep deprived for 60 h (E) or performed similar daily activities and slept 7 h per night (C). Performance variables were evaluated at the same time intervals during both conditions. No significant differences were observed between the E and C conditions for EMRT (pre-motor time, electromechanical delay, total reaction time) or muscular performance (MVC, RFD). The results suggest that subjects who have undergone 60 h of SD can react as fast, and with as much force, as those who have had 7 h of sleep per night.

Tikuisis, P., & Gonzalez, R. R. (1988). **Rational considerations for modelling human thermoregulation during cold water immersion.** *ASHRAE Trans., 94*(1), 1361-1370.

Abstract Immersion in cold water brings about large changes in body temperature and metabolism that add to the complexity of modeling human thermoregulation. Three specific problems peculiar to such modeling are examined; they are (1) finite-difference solution of the bioheat equation; (2) differences between predicted and measured initial conditions; and (3) prediction of convective heat loss. An optimization of the finite-difference solution of the simpler, but related, heart conduction problem is presented. A greater benefit is obtained by increasing the number of nodes rather than decreasing the integration time interval. A procedure is given for matching the predicted and measured initial values of the deep body temperature and the metabolic rate, which allows a more accurate determination of set-point values for thermoregulation. To circumvent the acute sensitivity to the skin-water temperature difference using the conventional prediction of convective heat loss, use of a heat balance during steady state of the skin temperature is outlined.

Tikuisis, P., Gonzalez, R. R., Oster, R. A., & Pandolf, K. B. (1988). **Role of body fat in the prediction of the metabolic response for immersion in cold water.** *Undersea Biomed. Res., 15*(2), 123-134.

Abstract Several empirical models for predicting the metabolic response to a lowered body temperature have been evaluated against available data of young healthy males immersed in cold water under resting conditions. Nude immersions took place in 20 and 24°C water for 1 h, and clothed immersions took place in 10 and 15°C for 3 h. The data were pooled according to low and high percent body fat (%BF). Decreases in the mean weighted skin temperature (Ts) ranged from 5.3 to 11.9°C and decreases in the core temperature (Tc) ranged from 0.56 to 1.54°C, while increases in the metabolic rate over the immersion period ranged from 34 to 256 W. Through regression analysis, an inverse relationship between %BF and the metabolic response for a given lowered Tsk and lowered Tc was established. When this relationship was explicitly applied to the models, significant improvements in their predictive capability were found. Variables such as body weight, body surface area, and the rate of change of Tsk were not found to contribute to the predictive capability of the models.

Tikuisis, P., Gonzalez, R. R., & Pandolf, K. B. (1988). **Thermoregulatory model for**

immersion of humans in cold water. *J. Appl. Physiol., 64*(2), 719-727.

Abstract The mathematical models of thermoregulation of Stolwijk and Hardy, and Montgomery were used to develop a model suitable for the simulation of human physiological responses to cold-water immersion. Data were obtained from experiments where 1:1 healthy male volunteers were totally immersed under resting and nude conditions for 1 h in water temperatures of 20 and 28°C. At these temperatures, the mean measured rectal temperature (Tre) fell by ≈0.9 and 0.5°C, respectively, yet mean measured metabolic rate (M) rose by ≈275 and 90 W for the low body fat group (n = 7) and 195 and 45 W for the moderate body fat group (n = 6). To predict the observed Tre and M values, the present model 1) included thermal inputs for shivering from the skin independent of their inclusion with the central temperature to account for the observed initial rapid rise in M, 2) determined a thermally neutral body temperature profile such that the measured and predicted initial values of Tre and M were matched, 3) confined the initial shivering to the trunk region to avoid an overly large predicted initial rate of rectal cooling, and 4) calculated the steady-state convective heat loss by assuming a zero heat storage in the skin compartment to circumvent the acute sensitivity to the small skin-water temperature difference when using conventional methods. The last three modifications are unique to thermoregulatory modeling.

Tikuisis, P., Gonzalez, R. R., & Pandolf, K. B. (1988). **Prediction of human thermoregulatory responses and endurance time in water at 20 and 24°C.** *Aviat. Space Environ. Med., 59*, 742-748.

Abstract A multi-compartmental mathematical model for predicting human thermoregulatory responses was applied to immersion in moderately cold water. Data were used from experiments where eight healthy male volunteers were immersed nude and up to the neck for I h in water at 20 and 24°C under conditions of rest and exercise. Rectal temperature and metabolic rate were measured before and during immersion. Once agreement between the model prediction and experimental observation was obtained, the model was used for prediction beyond the duration of the experiment. Stabilization of core temperature was predicted after 4-5 h of immersion for rest and after 2-4 h for exercise. Stabilization for resting individuals has been observed in other experiments under similar conditions. These results suggest that linear extrapolations based on linear body cooling rates are inadequate for predicting endurance times in moderately cold water. In this study, predicted endurance times were based on the concept of relative exercise intensity and are in agreement with the limited data available.

Vallerand, A. L., Frim, J., & Kavanagh, M. F. (1988). **Plasma glucose and insulin responses to oral and intravenous glucose in cold-exposed humans.** *J. Appl. Physiol., 65*, 2395-2399.

Abstract Although glucose tolerance and skeletal muscle glucose uptake are markedly improved by cold exposure in animals, little is known about such responses in humans. This study used two variations of a glucose tolerance test (GTT) to investigate changes in carbohydrate metabolism in healthy males during nude exposure to cold. In *experiment 1*, an oral GTT was performed in the cold and in the warm (3 h at 10 or 29°C). To bypass the gastrointestinal tract, and to suppress hepatic glucose output, a second experiment was carried out as described above, using an intravenous GTT. Even though cold exposure raised metabolic rate >2.5 times, plasma glucose and insulin responses to an oral GTT remained unaltered. In contrast, cold exposure reduced the entire plasma glucose profile as a function of time

during the intravenous GTT ($P < 0.05$), as plasma glucose was returned to basal levels within 1 h in comparison to a full 2 h in the warm, despite low insulin levels. The results of the intravenous GTT demonstrate that even with low insulin levels, carbohydrate metabolism is increased in cold-exposed males. This effect could be masked in the oral GTT by gastrointestinal factors and a high hepatic glucose output. Cold exposure may enhance insulin sensitivity and/or responsiveness for glucose uptake, mainly in shivering skeletal muscles.

1989

Bell, D. G., & Jacobs, I. (1989). **Muscle fiber-specific glycogen utilization in strength-trained males and females.** *Med. Sci. Sports Exercise, 21*(6), 649-654.

Abstract This study evaluated the effect of strength training on glycogen utilization in slow twitch (ST) and fast twitch (FT) muscle fibers during repeated maximal unilateral isokinetic leg extensions at 180°/s. Strength trained (5 males, 4 females) and untrained (4 males, 6 females) subjects performed 3 sets of 50 maximum voluntary contractions (MVC) at this velocity with 10 min rest intervals between sets. Biopsies were taken from the vastus lateralis muscle before and after each exercise session. Glycogen content of the fibers was quantified as optical density (OD) using microspectrophotometric densitometry on serial cross sections of muscle tissue stained with a periodic acid/Schiff reagent stain after individual fibers were identified as ST or FT according to a stain for myofibrillar ATPase activity. Analysis of variance with repeated measures yielded the following results: OD, i.e. glycogen, was reduced similarly in both fiber types after exercise, but only in the males ($p=0.02$); there was no significant main effect of training status per se (i.e. strength-trained vs. untrained). These results indicate that years of strength training do not change the pattern of muscle fiber-specific glycogen utilization during repeated dynamic MVCs.

Ducharme, M. B., Larochelle, J., & Richard., D. (1989). **Thermogenic capacity in gray and black morphs of the gray squirrel, Sciurus carolinensis.** *Physiol. Zool., 62,* 1273-1293.

Abstract During cold exposure, winter-acclimatized gray squirrels are capable of a peak metabolic rate 13.5 times their predicted standard metabolic rate (SMR). Some 20%-25% of the cold-induced beat production is due to nonshivering thermogenesis (NST). The remainder is attributed to shivering and indicates a capacity to reach a metabolic rate 10 times the predicted SMR by shivering. This performance ranks among the highest reported for homeothermic animals. In contrast to shivering, NST is subjected to seasonal variation in the gray squirrel. The maximum noradrenaline-invoked thermogenesis is 3.2-3.5 times greater in cold-acclimatized than in warm-acclimatized animals. This is primarily interpreted as a means to extend the thermal zone over which muscles can be freely allocated to activities other than shivering. While the heat production induced by cold is independent of color morph in warm-acclimatized squirrels, black individuals have a greater NST capacity (by 11%) and a lesser rate of estimated heat loss in the cold (by 18% at - 10°C) than gray ones. These results are consistent with the reported predominance of melanistic morphs in the northern part of the species' distribution.

Frim, J. (1989). **Head cooling is desirable but not essential for preventing heat strain in pilots.** *Aviat. Space Environ. Med., 60,* 1056-1062.

Abstract Liquid-cooled garments (LCGS) are being considered for reducing heat strain in pilots. While head cooling has been shown to be thermally efficient and

subjectively desirable, It is technically difficult to achieve. This laboratory study was carried out to see if head cooling in addition to torso cooling is a necessity. Six male subjects wore a cooling vest and cap under summer flight clothing on three occasions in a climatic chamber set at T_{db} = 42°C, T_{wb} = 32°C (RH = 50%), T_g = 52°C at head position, WBGT = 35°C. Cooling conditions were: control (CTRL), no fluid circulation; condition VEST, only torso cooling; condition HEAD, both torso and head cooling. Cooling fluid was circulated from a reservoir maintained at 10°C. Subjective thermal comfort assessments confirmed the desirability of head cooling, but performance measurements and physiological measurements of thermal strain showed no statistically significant differences between conditions VEST and HEAD. It was concluded that head cooling is desirable but not essential.

Graham, K. S., & McLellan, T. M. (1989). **Variability of time to exhaustion and oxygen deficit in supramaximal exercise.** *Aust. J. Sci. Med. Sport, 21,* 88-90.

Abstract To examine the variance in time to exhaustion (TE) and oxygen deficit (O2D) in supramaximal exercise, four trained male cyclists repeated rides at an intensity equivalent to 120% $\dot{V}O_2max$ power output. Oxygen deficit was calculated as the difference between the predicted oxygen consumption and the measured oxygen consumption. Individual coefficients of variation (CV) of 8.6-12.6% for TE and, 7.9-12.5% for 02D were reported. No significant differences in TE or O2D were determined across the four tests ($p > 0.05$). It is concluded that the oxygen deficit may be a reliable means of assessing changes in anaerobic capacity in training or metabolic studies designed to improve understanding of glycolytic processes.

Jacobs, I., Van Loon, D., Pasut, L., Pope, J., Bell, D., Kavanagh, M., Beach, A., Scherzinger, M., & Kerrigan-Brown, D. (1989). ***Physical performance and carbohydrate consumption in CF commandos during a 5-day field trial.*** (DCIEM 89-RR-48). Defence & Civil Institute of Environmental Medicine.

Abstract This study evaluated the capacity of military personnel to perform maximal exercise before and after 5 days of sustained physical activity. An additional goal was to evaluate whether a carbohydrate supplement to the regular field rations would reduce the extent of any performance impairments. Subjects (Ss) were 29 male volunteers from the Canadian Forces Airborne Regiment. They were allowed 4-5 h sleep each 24 h and 45 min per meal, but were otherwise continuously occupied with physically demanding missions in a field environment. Mean 24 h energy expenditure in the field was estimated from continuous HR recordings and direct oxygen uptake measurements with field portable equipment, and ranged from 5500 to 6500 kcal. Nutritional energy consumption of regular field rations (Individual Meal Packets, IMP) was carefully monitored; regular IMPS, containing about 3600 kcal/day were distributed to half of the Ss, while the remaining Ss were free to eat IMPs but were also instructed to consume starch candies containing 240 g carbohydrates (960 kcal) each day. Performance tests administered 2 days before and at the end of the 5-day field trial included evaluations of maximal aerobic power during cycle exercise, anaerobic power, muscular strength and endurance, rate of maximal force development and reaction time. Muscle and blood tissue samples were obtained before and after the trial to clarify the relative contribution of fat and carbohydrate energy stores to meeting the metabolic cost of the field trial. The results demonstrated that the Ss were in a marked negative caloric balance by the end of the field trial. Skeletal muscle glycogen stores were markedly depleted. In association with

these changes there were significant impairments at the end of the trial in maximal aerobic power, maximal dynamic strength, and anaerobic power of large muscle groups. These observations have direct implications for mission planning and physical performance expectations of military units involved in sustained operations.

Leatt, P., & Jacobs, I. (1989). **Effect of glucose polymer ingestion on glycogen depletion during a soccer match.** *Can. J. Sport Sci., 14,* 112-116.

Abstract The effect on muscle glycogen utilization of drinking a glucose polymer solution before and during a soccer match was studied. Ten male soccer players were divided into two groups balanced both for playing position and between the two teams. Five players on the experimental team (ET) ingested 0.5 L of 7% glucose polymer solution 10 min before the game and at half-time. Five control team (CT) players ingested equal volumes of placebo at the same times. The players were biopsied in the vastus lateralis before and after the game. The change in muscle glycogen was less ($p < 0.01$) in ET (111 ± 24 mmol glucose units $\bullet$ kg^{-1} dry muscle) than in CT (181 ± 24 mmol $\cdot$ kg^{-1}). Blood glucose concentration was not changed after the game in either group. This study demonstrates that glucose ingestion reduces net muscle glycogen utilization in a field setting, i.e. soccer match play.

Martineau, L., & Jacobs, I. (1989). **Free fatty acid availability and temperature regulation in cold water.** *J. Appl. Physiol., 67,* 2466-2472.

Abstract The purpose of this study was to investigate whether a reduced availability of plasma free fatty acids (FFA) would impair human temperature regulation during cold exposure. Seven seminude male subjects were immersed on two occasions in 18°C water for 90 min or until their rectal temperature (T_{re}) decreased to 35.5°C. The immersion occurred after 2 h of intermittent oral ingestion of either nicotinic acid (NIC) or a placebo (PLAC). Plasma FFA levels immediately before the immersion were significantly lower in NIC (87 ± 15 µmo/L) than in PLAC (655 ± 116 µmol/L, $P < 0.05$). Although FFA levels increased by 73% in NIC during the immersion ($P < 0.05$), they remained significantly lower than in PLAC (151 ± 19 vs. 716 ± 74 µmol/L, $P < 0.05$) throughout the immersion. Muscle glycogen concentrations in the vastus lateralis decreased after cold water immersion in both trials ($P < 0.05$), but the rate of glycogen utilization was similar, averaging 1.00 ± 0.27 mmol glucose unit $\cdot$ kg dry muscle $\cdot$ min^{-1}). Plasma glucose levels were significantly reduced after immersion in both trials ($P <$ 0.05), this decrease being greater in NIC (1.3 ± 0.2 µmol/L) than in PLAC (0.7 ± 0.1 µmol/L, $P < 0.05$). O_2 uptake increased to 3.8 ± 0.3 times preimmersion values in both trials ($P < 0.05$). Mean respiratory exchange ratio (RER) immediately before the immersion was greater in NIC (0.87 ± 0.02) than in PLAC (0.77 ± 0.01, $P < 0.05$). Cold exposure increased RER in PLAC but not in NIC. There was no intertrial difference in the calculated total metabolic heat production during immersion, averaging $1,380 \pm 221$ kJ. Similarly, the rate at which T_{re} decreased averaged 1.3 ± 0.4°C/h for both trials. These results indicate that a reduced availability of FFA does not impair human temperature regulation during cold water immersion. Apparently, any reduced heat production transduced from FFA was compensated by increased oxidation of other lipid sources or of circulating carbohydrates in NIC compared with PLAC.

Martineau, L., & Jacobs, I. (1989). **Muscle glycogen availability and temperature regulation in humans.** *J. Appl. Physiol., 66,* 72-78.

Abstract The effects of intramuscular glycogen availability on human temperature regulation were studied in eight seminude subjects immersed in 18°C water for 90 min or until rectal temperature (T_{re}) decreased to 35.5°C. Each subject was immersed three times over a 3-wk period. Each immersion followed 2.5 days of a specific dietary and/or exercise regimen designed to elicit low (L), normal (N), or high (H) glycogen levels in large skeletal muscle groups. Muscle glycogen concentration was determined in biopsies taken from the vastus lateralis muscle before and after each immersion. Intramuscular glycogen concentration before the immersion was significantly different among the L, N, and H trials ($P < 0.01$), averaging 247 ± 15, 406 ± 23, and 548 ± 42 (SE) mmol glucose units · kg dry muscle^{-1}, respectively. The calculated metabolic heat production during the first 30 min of immersion was significantly lower during L compared with N or H ($P < 0.05$). The rate at which T_{re} decreased was more rapid during the L immersion than either N or H ($P < 0.05$), and the time during the immersion at which T_{re} first began to decrease also appeared sooner during L than N or H. The results suggest that low skeletal muscle glycogen levels are associated with more rapid body cooling during water immersion in humans. Higher than normal muscle glycogen levels, however, do not increase cold tolerance.

McLellan, T. M., & Gass, G. C. (1989). **Metabolic and cardiorespiratory responses relative to the anaerobic threshold.** *Med. Sci. Sports Exerc., 21,* 191-198.

Abstract The present study has compared the metabolic and cardiorespiratory responses for two groups of male subjects during 20 min of exercise at the anaerobic threshold (AT), at AT+1/3, and at AT+2/3 of the difference (Δ) between AT and $\dot{V}O_2$ max. A log-log transformation of the lactate (LA)-power output relationship was used to define AT and divide subjects into a high ($N = 7$, AT = 51.9 ± 1.5% $\dot{V}O_2$ max) and low ($N = 5$; AT = 41.9 ± 1.8% $\dot{V}O_2$ max) AT group. No differences were observed between groups during exercise at AT for $VE{\cdot}VO2^{-1}$, $VE{\cdot}VCO2^{-1}$, pH, pCO2, blood LA, and plasma strong ions Na^+, K^+, and Cl^-. Although blood LA values were significantly elevated for the low AT subjects (2.3 ± 0.6 mmol·l^{-1},) compared with the high AT group (1.0 ± 0.1 mmol·l^{-1},) during exercise at AT+1/3Δ, no other differences between groups were noted. In contrast, marked differences were observed between groups during exercise at AT+2/3Δ. The high AT group showed no change in VE (79.1 ± 4.8 l·min^{-1}), pH (7.367 ± 0.01), pCO2 (37.3 ± 1.2 mm Hg), and blood LA (2.9 ± 0.3 mmol·l^{-1}) during the final 10 min of the 20 min exercise test. The low AT group, however, showed a progressive increase in VE (from 88.7 ± 4.2 to 108.0 ± 8.0 l·min^{-1}) and blood LA (from 8.6 ± 1.0 to 11.4 ± 2.7 mmol·l^{-1}) and a progressive decrease in blood pH (from 7.294 ± 0.014 to 7.251 ± 0.030) and pCO2 (from 35.2 ± 1.2 to 29.2 ± 1.3 mm Hg) from minute 10 to minute 20 of exercise. These data suggest that AT and $\dot{V}O_2$ max do not provide common reference points for calculating exercise intensity and/or that a metabolic rate exists above AT and below $\dot{V}O_2$max that defines an individual's maximal steady state for the cardiorespiratory and metabolic response to exercise.

McLellan, T. M., & Gass, G. C. (1989). **The relationship between the ventilation and lactate thresholds following normal, low or high carbohydrate diets.** *Eur. J. Appl. Physiol., 58,* 568-576.

Abstract Five men performed an incremental exercise test following a normal, low and high carbohydrate dietary regimen

over a 7-day period, to examine the influence of an altered carbohydrate energy intake on the relationship between the ventilation (VET) and lactate (LaT) thresholds. VET and LaT were determined from the ventilatory equivalents for O_2 ($VE \cdot \dot{V}O_2^{-1}$) and CO_2 ($VE \cdot VCO_2^{-1}$) and the log-log transformation of the lactate (La) to power output relationship, respectively. The total duration of the incremental exercise test, carbon dioxide output (VCO_2), respiratory exchange ratio, blood La values and arterialized venous partial pressure of CO_2 (pCO_2) were reduced, and $VE \cdot VCO2^{-1}$, the slope of the VE – VCO_2 relationship, blood ß-hydroxybutyrate and pH were increased during the low carbohydrate trial compared with the other conditions. Total plasma protein and Na^+, K^+, and Cl^- were similar across conditions. LaT and VET were unaffected by the altered proportions of carbohydrate in the diets and occurred at a similar oxygen consumption (mean $\dot{V}O_2$, across trials was 1.98 $L \cdot min^{-1}$ for VE T and 2.01 $L \cdot min^{-1}$ for LaT). A significant relationship (r=0.86) was observed for the $\dot{V}O_2$, that represented individual VET and LaT values. The increased $VE \cdot VCO_2^{-1}$, and slope of the V_E – VCO_2, relationship could be accounted for by the lower PCO_2. It is concluded that alterations in carbohydrate energy intake do not produce an uncoupling of VET and LaT as has been reported previously.

McLellan, T. M., & Jacobs, I. (1989). **Active recovery, endurance training, and the calculation of the individual anaerobic threshold.** *Med. Sci. Sports Exercise, 21,* 586-592.

Abstract The individual anaerobic threshold (IAT) is the highest metabolic rate at which blood lactate (LA) concentrations are maintained at a steady state during prolonged exercise. The purpose of this study was to compare the effects of active and passive recovery on the determination of the IAT before and after an endurance training program. Both before and after an 8-wk training program, nine subjects did two submaximal, incremental cycle exercise tests (30 W and 4 min per step) until LA was ≥ 4 $mmol \cdot l^{-1}$. Blood was sampled repeatedly during exercise and for 12 min during the subsequent recovery period, which was passive for one test and active (~ 35% $\dot{V}O_2$ max) during the second test. An IAT metabolic rate and power output were calculated for the passive (IATp) and active (IATa) recovery protocol. On separate days, before and after training, five of the subjects exercised for 30 min at either the IATp or the IATa. Before training, IATa occurred at a higher ($P < 0.05$) power output and absolute and relative $\dot{V}O_2$ compared to IATp. After training, $\dot{V}O_2$ max, and the power output and $\dot{V}O_2$ at IATa and IATp increased significantly; as a percent $\dot{V}O_2$ max, IATp but not IATa increased. During the pretraining 30-min IAT rides, LA was higher during the IATa than the IATp test, but LA values did not change during the last 20 min of exercise. LA was similar for both 30-min IAT rides after training and did not change from 5 to 30 min of exercise. The LA steady-state concentrations ranged from 1.3 to 6.8 $mmol \cdot l^{-1}$. The results demonstrate that the calculated IAT is higher after endurance training and when the recovery portion of the IAT test protocol is active; this latter effect is negligible in trained subjects.

Shibata, H., Pérusse, F., Vallerand, A., & Bukowiecki, L. J. (1989). **Cold exposure reverses inhibitory effects of fasting on peripheral glucose uptake in rats.** *Am. J. Physiol., 257*(Regulatory Integrative Comp. Physiol. 26), R96-R101.

Abstract The effects of fasting and cold exposure on glucose uptake in skeletal

muscles (tibialis anterior, quadriceps, and soleus), heart, and brown adipose tissue (BAT) were studied in conscious rats. Glucose uptake was estimated by determining the glucose metabolic index of individual tissues using the 2-[^{3}H]deoxyglucose method. Fasting for 18 h at 25°C decreased plasma glucose levels (-40%) and glucose uptake in heart (-95%) and skeletal muscles (-64-90%) but did not significantly affect glucose uptake in BAT. Fasting for 48 h did not further decrease these parameters. On the other hand, cold exposure (48 h at 5°C) of fed animals did not alter plasma glucose levels but increased glucose uptake in heart (73%), skeletal muscles (126-326%), and particularly in BAT (95-fold). Remarkably, cold exposure stimulated glucose uptake in BAT and skeletal muscles of 18-h fasted rats by the same order of magnitude as in fed animals (percentage wise), thereby indicating that glucose represents an essential metabolite for shivering (muscles) and nonshivering (BAT) thermogeneses. In the heart of starved animals, the cold-induced increase in glucose uptake was even more important (8-fold) than in fed animals. Considering that cold exposure of fasted rats results in a severe insulinopenia, it is suggested that cold exposure stimulates glucose uptake in peripheral tissues primarily by enhancing glucose oxidation via insulin-independent pathways.

Symons, J. D., & Jacobs, I. (1989). **High intensity exercise performance is not impaired by low intramuscular glycogen.** *Med. Sci. Sports Exercise, 21,* 550-557.

Abstract The purpose of this study was to evaluate the effects of glycogen availability on short-term, high-intensity exercise performance. Eight males completed performance evaluation tasks (PET) consisting of maximum isokinetic strength and endurance, isometric strength, and electrically evoked force of the leg extensors, twice during each of two conditions. On day 1 (D1) of the control condition (C) subjects performed the PET, followed by strenuous exercise designed to deplete glycogen stores of the leg extensors. After consuming a mixed diet for 48h (days 2 and 3) they performed the PET again on day 4 (D4). The experimental condition (E) was identical to C, except that a strictly controlled low carbohydrate diet was consumed during Days 2 and 3. Biopsies from the vastus lateralis before the PET on D4 confirmed differences between conditions in intramuscular glycogen (426 ± 43 vs 153 ± 60 mmol glucose units · kg^{-1} d.w. for C and E respectively, $P < 0.00$ 1). Results obtained from the PET were not different between conditions on D4, nor within conditions when D1 and D4 were compared. Resting blood glucose, hematological variables indicative of hydration and acid-base status, and post PET blood lactate were similar for all trials. It is concluded that short-term, high-intensity exercise performance of glycogen depleted leg extensors is not impaired.

Tikuisis, P. (1989). **Prediction of the thermoregulatory response for clothed immersion in cold water.** *Eur. J. Appl. Physiol., 59*(5), 334-341.

Abstract A multi-compartmental thermoregulatory model was applied to data of ten resting clothed males immersed for 3 h in water at 10 and 15°C. Clothing consisted of a dry suit and either a light or heavy undergarment, representing a total insulation of 0.15 (0.95) or 0.20 m^2°CW^{-1} (1.28 clo), respectively. Data were grouped according to low (< 140%) and high (14 to 240/o) body fat individuals. Mean decreases in rectal temperature ranged from 0.79 to 1.38°C, mean decreases in the mean weighted skin temperature ranged from 6.3 to 10.2°C, and mean increases in the metabolic rate ranged from 33.9 to 80.8 W. The model consists of eight segments, each representing a specific region of the body. Each segment is comprised of compartments representing the core, muscle, fat, skin, and clothing. Each compartment is assigned thermophysical values of heat con-

duction and heat capacitance, and with the exception of clothing, physiological values of blood flow and metabolic heat production. During cold exposure, responses are directed towards increased heat production in the form of shivering and heat conservation in the form of vasoconstriction and convective heat exchange at the vascular level. Agreement between the model predictions and the experimental observations was obtained by adjusting the parameters governing these responses. These adjusted parameters were 1) the onset of limb shivering with an exponential half-time of 30 min, 2) the fractional value of 0.5 for the convective heat exchange between the' core compartments of the limbs and the blood flowing through these compartments, 3) the fractional contribution of trunk shivering to overall shivering, which ranged from 0.77 to 0.95, and 4) the onset of vasoconstriction with exponential half-times that ranged from 3 to 25 min. Steady state wits predicted to occur within 4 h and a heat balance analysis indicated that the limbs were responsible for most of the body's heat loss while acquiring most of their own heat from the trunk through convective heat exchange with the central blood.

Vallerand, A. L., & Jacobs, I. (1989). **Rates of energy substrates utilization during human cold exposure.** *Eur. J. Appl. Physiol, 58,* 873-878.

Abstract Although it is well established in animals that acute cold exposure markedly increases the oxidation of energy substrates, the absolute quality and quantity of substrate oxidation is poorly understood in humans. This study compared the rates of substrate utilization in seven healthy young men exposed to both the warm (control exposure at 29°C; semi-nude, 14 h fasted) and to the cold for 2 h (10°C, 1 m · s^{-1} wind velocity). Substrate utilization was calculated using indirect calorimetry and the nonprotein respiratory exchange ratio, which was derived from the urinary urea nitrogen output. Cold exposure induced a 3.1±0.2°C drop in mean body temperature and a body heat debt of 825.9±63.3 kJ (p<0.01). These parameters remained essentially unchanged in the warm. Cold exposure elevated the 2 h energy expenditure 2.46-fold in comparison to the warm (p<0.01). This cold-induced thermogenesis was accompanied by increases of 588% in carbohydrate oxidation (p<0.01) and 63% in fat oxidation (p<0.05), whereas protein oxidation remained unchanged. Although the greatest proportion of the energy expenditure in the warm was derived from lipid (59%), carbohydrate oxidation represented the major fuel for thermogenesis in the cold, since it accounted for 51% of the corresponding total energy expenditure. The results demonstrate that cold exposure causes a much greater increase in the utilization of carbohydrate than lipid. It is suggested that these substrates are directly utilized for thermogenesis in the shivering skeletal muscles.

Vallerand, A. L., Jacobs, I., & Kavanagh, M. F. (1989). **Mechanism of enhanced cold tolerance by an ephedrine-caffeine mixture in humans.** *J. Appl. Physiol., 67,* 438-444.

Abstract The influence of a thermogenic mixture of ephedrine- (1 mg/kg) caffeine (2.5 mg/kg) on cold tolerance was investigated in nine healthy young male subjects during two seminude exposures to cold air (3 h at 10°C). The drug ingestion reduced the total drop in core, mean skin, and mean body temperatures (P < 0.01), thus producing significantly warmer final core, mean skin, and mean body temperatures compared with the placebo ingestion. The drug ingestion increased the total 3-h energy expenditure by 18.6% compared with that of the placebo ingestion in the cold (P < 0.01). By means of the nonprotein respiratory exchange ratio to calculate the rates of substrate oxidation, it was found that the drug ingestion increased carbohydrate oxidation by as much as 41.7%

above that of the placebo ($P < 0.05$). In contrast, the drug mixture had no significant influence on lipid or protein metabolism. The results demonstrate that the ingestion of an ephedrine-caffeine mixture improves cold tolerance in humans by significantly increasing body temperatures in the cold. These improvements were not caused by an increased conservation of heat but by a greater energy expenditure, which appears to be dependent on an enhanced carbohydrate utilization.

Vallerand, A. L., Limmer, R., & Schmegner, I. F. (1989). **Computer acquisition and analysis of skin temperature and heat flow data from heat flux transducers.** *Computer Methods and Programs in Biomedicine, 30,* 279-282.

Abstract A computer-controlled system for the collection and analysis of skin temperature and heat flow data originating from an array of heat flux transducers is described. The system is based on a program ('THERMAL') that reads, stores, prints and displays skin temperatures and heat flow data every 2 rain for up to 4 h. It also simultaneously calculates important environmental physiology parameters such as mean skin and mean body temperatures as well as mean heat flow according to four different combinations of transducers such as the established 3-, 4-, 7- and 12-point (site) formulae. Core temperature, heart rate and environmental condition indices such as dry bulb, wet bulb and globe temperatures are also continuously monitored.

Vallerand, A. L., Wang, L., & Jacobs, I. (1989). ***Influence of theobromine on heat production and body temperatures in cold-exposed humans: a preliminary report.*** (DCIEM 89-RR-50). Defence & Civil Institute of Environmental Medicine.

Abstract One of the most successful class of drugs employed to enhance cold tolerance in animals appears to be the methylxanthines. Indeed, methylxanthines such as caffeine, theophylline and theobromine have been shown to increase heat production, delay hypothermia and thus improve cold tolerance in animals. In humans, theophylline and caffeine (taken in combination with ephedrine) have similarly been shown to improve cold tolerance. Whether theobromine could enhance tolerance to cold in humans, is not known. The influence of theobromine was thus investigated in eight healthy young male subjects during two semi-nude exposures to cold air (3h, 7°C, 1 m/s wind speed). The ingestion of theobromine (7.5 mg/kg at min 0; double-blind placebo-controlled trial) produced two different types of responses, as shown by a significant interaction between the effect of group (responders vs non-responders) and the effect of drug treatment (placebo vs theobromine) on the rate of decrease in mean body temperatures (T_b). This interaction indicates that the effect of theobromine significantly changed as a function of the groups of subjects. Four subjects showed a significant reduction (or improvement) in the drop in T_{sk} and T_b with theobromine ingestion, ($P<0.05$), whereas their core temperature (T_{re}) was not significantly affected by the drug treatment. These improvements were also associated with a 20% increase in heat production (not significant) and a 70% greater lipid oxidation ($P=0.08$). These 4 subjects were therefore considered as "responders" to the drug treatment. In addition, the other four subjects were considered as "non-responders", since their drop in T_{sk}, drop in T_b and heat production remained unchanged by the ingestion of theobromine. However, their drop in T_{re} following the ingestion of theobromine was not smaller, but significantly greater than with the placebo ingestion (51%, $P<0.05$). The main difference between "responders" and "non-responders" in their placebo responses to the cold appeared to be the 25% lower heat production and the corresponding 52% greater T_{re} cooling rate of the non-responders compared to the responders. In conclusion,

the present results are interpreted as indicating that under resting conditions, the ingestion of theobromine in subjects capable of producing a relatively high metabolic response to the cold, significantly improves cold tolerance by increasing heat production, mainly from a greater lipid utilization. Although theobromine did not significantly alter tolerance to cold in resting subjects with a relatively low metabolic response to cold, it significantly worsened their rate of T_{re} cooling, a side effect which suggests that theobromine should be used with caution. Future work must be carried out to optimize the beneficial influence of theobromine and to minimize its side effect in cold-exposed humans.

1990

Bell, D. G., & Jacobs, I. (1990). **Muscle fibre area, fibre type, and capillarization in male and female body builders.** *Can. J. Sport Sci., 15*(2), 115-119.

Abstract The effects of long term strength training on skeletal muscle fibre characteristics were evaluated in nine body builders (BB) (5 males and 4 females) and ten control subjects (6 females and 4 males). Muscle fibre area, percent fibre type, and capillary supply were compared between the BB and controls as well as between the males and females with a two-way analysis of variance design. For the fast twitch fibre area (FTa), the BB had larger areas than the controls and males had larger areas than females. The analysis for the slow twitch fibre areas (STa) showed only a training effect, BB had larger STa than controls. The FTa in the untrained females and the female BB were similar to their STa; in contrast, both male groups had significantly larger FTa than STa. The BB had significantly more capillaries per fibre than the control groups but the number of capillaries/mm^2 were similar in all groups. The results suggest that prolonged training in the female BB hypertrophies both the FT and ST fibres. The female BB realized the same increase in #cap/f as the male BB. However, the larger area of the FT fibres compared to the ST fibre seen in both male groups was not observed in either female group.

Cheung, B., Money, K., & Jacobs, I. (1990). **Motion sickness susceptibility and aerobic fitness: a longitudinal study.** *Aviat. Space Environ. Med., 61,* 201-204.

Abstract A longitudinal study evaluated the susceptibility to motion sickness in initially unfit subjects before and after an endurance training program. Motion stimulation was provided by the Precision Angular Mover, in which the subject was tumbled head over heels about an Earth-horizontal axis at 20 cycles per minute in darkness. Maximal aerobic power and the blood lactate response to submaximal exercise were evaluated with cycle ergometry. The training program caused significant improvements in $\dot{V}O_2max$ and endurance capacity, and a significant decrease in percent body fat. There was a significant ($p < 0.0125$) increase in motion sickness susceptibility after the physical training, suggesting that increased physical fitness caused increased susceptibility to motion sickness in some individuals.

Ducharme, M., Frim, J., & Tikuisis, P. (1990). **Errors in heat flux measurements due to the thermal resistance of heat flux disks.** *J. Appl. Physiol., 69*(2), 776-784.

Abstract Questions have been raised regarding the effect of the thermal resistance of heat flux transducers (HFTs) on the thermal flux from the skin. A model capable of simulating a large range of "tissue" insulation (variable-R model) was used to study the effect of the underlying tissue insulation on the relative error in heat flux due to the thermal resistance of the HFTs. The data

show that the deviation from the true value of heat flux increases as the insulation of the underlying tissue decreases ($r = 0.99$, $P < 0.001$). The underestimation of the heat flux through the skin measured by an HFT is minimal when the device is used on vasoconstricted skin in cool subjects (3-13% error) but becomes important when used during vasodilation in warm subjects (29-35% error) and even more important on metallic-skin mannequins (> 60% error).

Ducharme, M. B. (1990) *Effective insulative properties of the human forearm tissues.* Ph. D., University of Toronto.

Abstract The main objective of the present research work was to investigate the effect of a range of thermal stresses on the effective thermal conductivity of the skeletal muscles (keff muscle) and skin+subcutaneous fat tissues (keff skin+fat) of the resting human forearm, and to calculate the relative contribution of the forearm muscle tissues to the overall forearm tissue insulation. Fifteen male subjects immersed their forearm on two separate occasions in water ranging in temperature between 15 and 36°C for 3 hours. Tissue temperature (Tt) was continuously monitored by a calibrated multicouple probe implanted approximately 9 cm distal from the olecranon process along the ulnar ridge. It was measured every 5 mm, from the longitudinal axis of the forearm (determined from computed tomography scanning) to the skin surface. Along with Tt, forearm skin temperature (Tsk), arterial blood temperature at the distal brachial artery (Tbla), rectal temperature (Tre), forearm heat loss (Hsk) and forearm blood flow (Q) were measured during the experiments. For all temperature conditions, the temperature profile within the limb was linear as a function of the radial distance from the forearm axis ($p < 0.001$). The maximal tissue temperature was measured in all cases at the longitudinal axis of the forearm, and was in all experimental conditions lower than Tre. When more than ~90% of the thermal stability was achieved during cold stress at 15°C, 83% of the subjects tested showed evidence of the hunting reaction in the forearm; this phenomenon being limited to the muscle tissues. The values of keff skin+fat and keff muscle, calculated from the Finite-Element solution for Tw < 30°C, were not different from the average in vitro values obtained from the literature. The keff of the forearm tissues were linearly related ($r = 0.80$, $p < 0.001$) to the tissue blood flow for Tw > 30°C. The contribution of the muscle tissues to the overall forearm insulation was calculated to average 92 ± 1% during immersion in water between 15 and 36°C. This result suggests that the skeletal muscle is the main tissue responsible for the forearm insulation during cold stress and at neutral conditions in non-shivering resting humans.

Frim, J., & Duggan, A. (1990). *Thermal properties of five military footwear ensembles during static duties in a cold dry environment.* (APRE 90-M-503). Army Personnel Research Establishment, Farnborough, Hants., U.K.

Abstract This study compared the thermal properties of the in-service combat footwear ensemble with a new system currently being troop trialled as a potential replacement The comparison was made under conditions which simulated static duties in dry, sheltered conditions in a North German winter (dry bulb temperature –9°C). Through the use of heat flux transducers, it was shown that heat loss through the dual density polyurethane sole of the new boot was significantly less than through the in-service boot's rubber sole. Wearing a fabric-faced saran insole inside the new combat boot was found to reduce heat loss markedly, leading to the recommendation that this item should be used by all soldiers in cold environments. A water vapour permeable waterproof boot liner, on the other hand, was of little value in reducing heat loss from the foot or in maintaining foot temperatures under these dry

conditions. It was observed that neither the new nor the in-service footwear ensembles provided adequate protection from the environmental and operational conditions simulated in this study. There is a requirement, therefore, to provide extra thermal insulation for the feet of soldiers subjected to such conditions

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Frim, J., Livingstone, S., Reed, L., Nolan, R., & Limmer, R. (1990). **Body composition and skin temperature variation.** *J. Appl. Physiol., 68,* 540-543.

Abstract Temperature variations near four common torso skin temperature sites were measured on 17 lightly clad subjects exposed to ambient temperatures of 28, 23, and 18°C. Although variations in skin temperature exceeding 7°C over a distance of 5 cm were observed on individuals, the mean magnitude of these variations was 2-3°C under the coolest condition and less at the warmer temperatures. There was no correlation between the temperature variation and skinfold thickness at a site or with estimations of whole body fat content. These findings imply that errors in mean skin temperature measurement could arise from probe mislocation and/or subcutaneous fat distribution and that the problem becomes more acute with increasing cold stress. However, the magnitudes of these errors cannot be easily predicted from common anthropometric measurements.

Gati, R., Tabaraud, F., Buguet, A., Bert, J., Tapie, P., Bittel, J., Sparkes, B., Breton, J. C., Doua, F., Bogui, P., Lonsdorfer, A., Lonsdorfer, J., Moulin, J., Chameaud, J., & Dumas, M. (1990). **Analyse circadienne du sommeil, de la température rectale et de variables immunologiques et endocrinologiques dans la maladie du sommeil.** *Bull. Soc. Path. Ex., 83,* 1-8.

Abstract Une étude multidisciplinaire a été conduite chez 8 patients atteints de trypanasomiase humaine africaine au stade de méningoencéphalite. Elle a permis de confirmer le caractère ultradien du cycle veille-sommeil, caractère d'autant plus prononcé que le patient est plus gravement atteint sur le plan clinique. Le tracé électroencéphalographique est entrecoupé de phases d'activation transitoire extrêmement nombreuses associant des complexes K, des éléments rapides et des éléments lents. Le rythme circadien de différentes variables physiologiques (température rectale), immunologiques (interleukines) ou endocriniennes (cortisol, prolactine) est également perturbé, les perturbations du caractère circadien étant également majeures chez les malades les plus touchés.

Grisdale, R., Jacobs, I., & Cafarelli, E. (1990). **Relative effects of glycogen depletion and previous exercise on muscle force and endurance capacity.** *J. Appl. Physiol., 69,* 1276-1282.

Abstract Endurance capacity of human vastus lateralis muscles was observed 24 h after hard exercise followed by either a carbohydrate-restricted or a carbohydrate-loaded diet (depletion and repletion conditions). In a control condition the subjects did no previous exercise and ate their normal diet. Each of these conditions was followed by an experimental protocol in which the five male subjects made a series of alternating 25-s static contractions of each leg at 50% maximal voluntary contraction until one leg failed to achieve the required force (T_{lim}). Glycogen concentration before the experimental protocol in both legs was significantly lower in the depletion than in the repletion condition. Muscle lactate and creatine phosphate concentrations were within normal limits before the static contractions. The number of contractions the repleted (12.7 ± 2.2) and depleted (10.3 ± 1.5) legs could sustain before T_{lim} were not different from each

other, but both were 35% ($P < 0.05$) fewer than the control (17.6 ± 3.0). Surface electromyogram (EMG) amplitude was higher in depleted than in repleted or control muscles. At T_{lim}, EMG amplitude was maximal, creatine phosphate was 50-70% depleted. and lactate increased fourfold. Average glycogen utilization per contraction in both the repletion and depletion conditions was 5.8 mmol/kg dry wt, but post exercise lactate concentrations were lower in depleted (14.4 ± 3.6 mmol/kg dry wt) than in repleted (43.2 ± 7.4) muscles. The EMG frequency distribution shifted downward in all conditions during the experimental protocol and was independent of muscle lactate concentration. We have drawn the following conclusions about this form of exercise from these data: 1) previous exercise is a more potent determinant of muscle endurance capacity than glycogen availability and 2) glycogen depletion, previous exercise. and lactate accumulation do not influence the shift in the EMG frequency distribution.

Jansson, E., Esbjörnsson, M., Holm, I., & Jacobs, I. (1990). **Increase in the proportion of fast-twitch muscle fibres by sprint training in males.** *Acta Physiol. Scand., 140,* 359-363.

Abstract Fifteen male physical education students were studied. The subjects trained for 4-6 weeks, 2-3 days per week, on a mechanically braked bicycle ergometer. A training session consisted of repeated 30-s 'all-out' sprints on a Wingate bicycle ergometer, on which the brake band of the flywheel was loaded with 75 g kg^{-1} body wt, with rest periods of 15-20 min between consecutive sprints. Thigh muscle biopsies were taken before and after the training period and were analysed for fibre types using a myofibrillar ATPase stain. The proportion of type I fibres decreased from 57 to 48% ($P < 0.05$) and type IIA fibres increased from 32 to 38% ($P < 0.05$). This study indicates that it is possible to achieve a fibre type transformation with high-intensity training. The effect of two-legged 'sprint' training on muscle fibre type composition may be related to a changed pattern of muscle fibre activation (e.g. an increased stimulation frequency). A change in fibre activation frequency may induce an increased synthesis of type II fibre myosin (fast myosin). Hormonal influences such as enhanced adrenergic stimulation of the muscle fibres cannot be excluded as a contributing factor, however.

Kuzon, W. M., Rosenblatt, J. D., Huebel, S. C., Leatt, P., Plyley, M. J., McKee, N. H., & Jacobs, I. (1990). **Skeletal muscle fiber type, fiber size, and capillary supply in elite soccer players.** *Int. J. Sports Med., 11,* 99-102.

Abstract This study determined the fiber type composition, the fiber size, and the capillary characteristics of the vastus lateralis muscle in 11 young, elite, male soccer players and 8 sedentary male, age-matched controls. There were no significant differences ($P < 0.05$) in the fiber type percentages and fiber diameter between the soccer players and controls; however, all fiber types tended to be larger in the soccer players. The soccer players possessed a greater capillary supply; this was characterized by a significantly greater mean number of capillaries surrounding each fiber (5.7 ± 0.9 vs. 4.9 ± 0.4), a significantly larger capillary density (282.7 ± 42.0 vs. 220.8 ± 38.1), and a significantly higher capillary to fiber ratio (2.2 ± 0.6 vs. 1.7 ± 0.1). The results indicate that soccer may be an appropriate stimulus for simultaneous adaptation to endurance and high intensity exercise.

MacNaughton, K. W., Sathasivam, P., Vallerand, A.L., & Graham, T.E. (1990). **Influence of caffeine on metabolic responses of men at rest in 28 and 5°C.** *J. Appl. Physiol., 68* (5), 1889-1895.

Abstract Cold stress and caffeine ingestion are each reported to increase plasma catecholamines, free fatty acid (FFA) concentrations, and energy metabolism. This study examined the possible interaction of these two metabolic challenges in four double-blind counterbalanced trials. Young adult men (n = 6) ingested caffeine (5 mg/kg) or placebo (dextrose, 5 mg/kg) and rested for 2 h in 28 or 5°C air. Cold stress alone elevated ($P < 0.05$) plasma norepinephrine, metabolism (O_2 consumption, $\dot{V}O_2$). and respiratory exchange ratio (RER). Caffeine alone increased ($P < 0.05$) plasma epinephrine and FFA but not RER. When the two challenges were combined (caffeine plus 5°C for 2 h) norepinephrine and epinephrine were increased ($P < 0.05$) as was FFA. However, $\dot{V}O_2$, RER, and skin and rectal temperatures were not different from the responses observed at 5°C after placebo ingestion. The data suggest that caffeine selectively increases plasma epinephrine, whereas cold air increases norepinephrine. During the cold exposure, increasing epinephrine and FFA above normal levels did not appear to influence the metabolic or thermal responses to the cold stress. In fact the increase in RER suggested a greater carbohydrate oxidation.

McLellan, T., Jacobs, I., & Bain, B. (1990). ***Heat strain and work tolerance times with varying levels of Canadian Forces NBCW protective clothing, ambient temperature, physical work intensity, and work/rest schedules.*** (DCIEM 90-51). Defence & Civil Institute of Environmental Medicine.

Abstract This study examined the effects of environmental temperature and metabolic rate on soldiers' work tolerance time (WTT) while wearing various levels of nuclear, biological and chemical (NBC) defence protective clothing. Twenty-three unacclimatized males (23 ± 3 y, 76 ± 8 kg, 1.77 ± 0.08 m) were assigned to exercise at either a light (walking 1.11 $m \cdot s^{-1}$ 0% grade, alternating with lifting 10 kg) or heavy metabolic rate (walking 1.33 $m \cdot s^{-1}$ 7.5% grade, alternating with lifting 20 kg) in an environmental chamber at either 18°C, 50% R.H. (cool) or 30°C, 50% R.H. (hot). Subjects were tested wearing three levels of clothing protection: combat fatigues (Low); fatigues and a semi-permeable NBC overgarment (Med); fatigues and NBC overgarment, gloves, boots and respirator (High). WTT was the time until rectal temperature (Tre) reached 39.3°C, heart rate reached 95% maximum, dizziness or nausea precluded further exercise, or 5 h had elapsed. During the hot trial, 8 subjects (light (N=4) and heavy exercise (N=4)) performed an additional three clothing trials using an intermittent rather than a continuous work schedule. During the light and cool trials (N=5), the levels of protective clothing did not impair WTT (277 ± 47 min). For the light and hot experiments (N=6), WTT was significantly impaired with the High level of protection (82.7 ± 10.6 min) and Tre increased 1.3 ± 0.3°C·h^{-1}. With the heavy and cool condition (N=6), WTT was reduced with the Med (240.5 ± 73.8 min, Tre increased 0.5 ± 0.2°C·h^{-1}) and High (56.7 ± 17.9 min, Tre increased 1.8 ± 0.5°C·h^{-1}) levels of protection. Finally, during the heavy and hot trials (N=6), WTT was progressively impaired for the Low (172.5 ± 52.8 min, Tre increased 0.8 ± 0.3°C·h^{-1}), Med (65.8 ± 18.2 min, Tre increased 2.0 ± 0.5°C·h^{-1}) and High (34.0 ± 9.7 min, Tre increased 2.6 0.5°C·h^{-1}) levels of protection. In the hot environment, the inverse of WTT was directly proportional to the average metabolic rate ($\dot{V}O_2$ (mL·kg^{-1}·min^{-1})) for both the Med (WTT^{-1}= 0.00129 $\dot{V}O_2$ - 0.0109, r = 0.9) and High (WTT^{-1}= 0.00167 $\dot{V}O_2$ - 0.0068, r = 0.9) levels of protection. If the metabolic rate of a task is known, these relationships can be used to calculate work to rest schedules that may prolong work time in the Med or High levels of NBC protective clothing.

McLellan, T., Kavanagh, M. F., & Jacobs, I. (1990). **The effect of hypoxia on performance during 30-s or 45-s of supramaximal exercise.** *Eur. J. Appl. Physiol., 60* , 155-161.

Abstract The purpose of this study was to evaluate the effect of hypoxia (10.8 ± 0.6% oxygen) on performance of 30 s and 45 s of supramaximal dynamic exercise. Twelve males were randomly allocated to perform either a 30 s or 45 s Wingate test (WT) on two occasions (hypoxia and room air) with a minimum of 1 week between tests. After a 5-min warm-up at 120 W subjects breathed the appropriate gas mixture from a wet spirometer during a 5-min rest period. Resting blood oxygen saturation was monitored with an ear oximeter and averaged 97.8 ± 1.5% and 83.2 ± 1.9% for the air (normoxic) and hypoxic conditions, respectively, immediately prior to the WT. Following all WT trials, subjects breathed room air for a 10-min passive recovery period. Muscle biopsies from the vastus lateralis were taken prior to and immediately following WT. Arterialized blood samples, for lactate and blood gases, were taken before and after both the warm-up and the performance of WT, and throughout the recovery period. Open circuit spirometry was used to calculate the total oxygen consumption ($\dot{V}O_2$), carbon dioxide production and expired ventilation during WT. Hypoxia did not impair the performance of the 30-s or 45-s WT. $\dot{V}O_2$ was reduced during the 45-s hypoxic WT (1.71 ± 0.21 l) compared with the normoxic trial (2.16 ± 0.26 l), but there was no change during the 30-s test (1.22 ± 0.11 vs. 1.04 ± 0.17 l for the normoxic and hypoxic conditions, respectively). Muscle lactate (LA) increased more during hypoxia following both the 30-s and 45-s WT (67.1 ± 25.0 mmol·kg^{-1} dry weight) compared with normoxia (30.8 ± 18.0 mmol·kg^{-1} dry weight). Hypoxia did not influence the change in intramuscular adenosine triphosphate, creatine phosphate and glucose-6-phosphate. The performance of WT during hypoxia was associated with a greater decrease in muscle glycogen ($P < 0.06$). Throughout the recovery period, blood LA was lower following the hypoxia (8.43 ± 2.88 mmol·l^{-1}) compared with normoxia (9.15 ± 3.06 mmol·l^{-1}). Breathing the hypoxic gas mixture prior to the performance of WT increased blood pH to 7.44 ± 0.03, compared with 7.39 ± 0.03 for normoxia. Blood pH remained higher during the 10-min recovery period following the hypoxic WT trials (7.24 ± 0.08) compared with the normoxic WT (7.22 ± 0.06). Blood PCO2 was reduced prior to and immediately following WT during hypoxia, but there were no differences between the normoxic and hypoxic trials during the 10 min recovery period. These data indicate that more energy was transduced from the catabolism of glycogen to lactate during the hypoxic WT trials, which offset the reduced O2 availability and maintained performance comparable with normoxic conditions. It is suggested that the induced respiratory alkalosis associated with breathing the hypoxic gas could account for the increased rate of muscle LA accumulation.

Sale, D.G., Jacobs, I., MacDougall, J.D., & Garner, S. (1990). **Comparison of two regimens of concurrent strength and endurance training.** *Med. Sci. Sports Exercise, 22* , 348-356.

Abstract To compare the responses to doing strength (S) training on alternate days with endurance (E) training vs. doing both types of training on the same days per week, seven young men (group A-2 d) did S and E training together in single sessions 2 d · wk^{-1} for 20 wk. A second group (B-4 *d*, N = 8) did the S training on 2 d · wk^{-1} and E training on 2 other d · wk^{-1}. S training was six to eight sets of 15-20 RM on a leg press weight machine. E training was six to eight 3-min bouts of cycle ergometer exercise at 90-100% $\dot{V}O_2$max. B-4 d (25%) increased leg press I *RM* more ($P < 0.05$) than A-2 d (13%), but the groups increased similarly (A-2 d, B-4 d) in knee extensor (31%, 34%) and flexor (I 2%,

14%) cross-sectional area and vastus lateralis mean fiber area (33%, 25%). Increases in $\dot{V}O_2max$, (7%, 6%), repetitions with 80% 1 RM (39%, 64%), repetitions with the pretraining 1 RM (33, 55), and PFK (19%, 10%) and LDH (15%, 23%) activity did not differ ($P > 0.05$) between groups. CS activity increased significantly only in A-2 d (26%; B-4 d, 6%). It is concluded that same day (vs. different day) concurrent strength and endurance training may impede strength development without impeding hypertrophy. On the other hand, same day training may enhance increases in CS activity but not $\dot{V}O_2max$ or weight lifting endurance.

Sale, D.G., MacDougall, J.D., Jacobs, I., & Garner, S. (1990). **Interaction between concurrent strength and endurance training.** *J. Appl. Physiol., 68* , 260-270.

Abstract To assess the effects of concurrent strength (S) and endurance (E) training on S and E development, one group (4 young men and 4 young women) trained one leg for S and the other leg for S and E (S+E). A second group (4 men, 4 women) trained one leg for E and the other leg for E and S (E+S). E training consisted of five 3-min bouts on a cycle ergometer at a power output corresponding to that requiring 90-100% of oxygen uptake during maximal exercise ($\dot{V}O_2max$). S training consisted of six sets of 15-20 repetitions with the heaviest possible weight on a leg press (combined hip and knee extension) weight machine. Training was done 3 days/wk for 22 wk. Needle biopsy samples from vastus lateralis were taken before and after training and were examined for histochemical, biochemical, and ultrastructural adaptations. The nominal S and E training programs were "hybrids," having more similarities as training stimuli than differences; thus S made increases ($P < 0.05$) similar to those of S+E in E-related measures of $\dot{V}O_2max$ (S, S+E: 8%, 8%), repetitions with the pretraining maximal single leg press lift [1 repetition maximum (RM)] (27%, 24%), and percent of slow twitch fibers (15%, 8%); and S made significant, although smaller, increases in repetitions with 80% 1 RM (81%, i52%) and citrate synthase (CS) activity (22%, 51%). Similarly, E increased knee extensor area [computed tomography (CT) scans] as much as E+S (14%, 21%) and made significant, although smaller, increases in leg press 1 RM (20%, 34%) and thigh girth (3.4%, 4.8%). When a presumably stronger stimulus for an adaptation was added to a weaker one, some additive effects occurred (i.e., increases in 1 RM and thigh girth that were greater in E+S than E; increases in CS activity and repetitions with 80% 1 RM that were greater in S+E than S). When a weaker, although effective, stimulus was added to a stronger one, addition generally did not occur. Concurrent S and E training did not interfere with S or E development in comparison to S or E training alone.

Vallerand, A.L., & Jacobs I. (1990). **Stimulatory effects of cold exposure and cold acclimation on glucose uptake in rat peripheral tissue.** *Am. J. Physiol., 259* (Regulatory Integrative Comp. Physiol. 28), R1043-R1049.

Abstract The effects of cold exposure on the net rates of 2-[^{3}H]deoxy-D-glucose uptake (K_i) in rat peripheral tissues were investigated comparatively in warm- and cold-acclimated animals to determine whether cold acclimation induces regulatory alterations in glucose metabolism. Acute exposure of warm-acclimated (25°C) rats to cold (48 h at 5°C) markedly increased the K_i values in red and white skeletal muscles (2-5 times), in the heart (8 times), in several white adipose tissue (WAT) depots (4-20 times), and in brown adipose tissue (BAT) (110 times). After cold acclimation (3 wk at 5°C), the K_i values further increased in the heart (15 times) and WAT (up to 29 times) but decreased in BAT (36 times). Remarkably, glucose uptake was still in-

creased in muscles of cold-exposed/cold-acclimated animals (that do not shiver), demonstrating that enhanced glucose uptake may occur in muscles in the absence of shivering thermogenesis (or contractile activity). When cold-acclimated rats were returned to the warm for 18 h, the K_i values of all tissues, except WAT, returned to control levels. Cold exposure synergistically potentiated the stimulation of tissue glucose uptake induced by a maximal effective dose of insulin (0.5 U/kg iv) in warm as well as in cold-acclimated animals. The data demonstrate that 1) activation of shivering and/or nonshivering thermogeneses by cold exposure results in a rapid increase of glucose uptake in peripheral tissues; 2) cold acclimation enhances the capacity of heart and WAT for cold-induced glucose uptake, but, with the exception of WAT, it does not induce long-term alterations in glucose metabolism; and 3) cold exposure, but not cold acclimation, increases insulin responsiveness (maximum velocity) in all tissues tested. The results also indicate that activation of nonshivering thermogenesis in BAT and muscles of cold-acclimated animals represents the principal phenomenon explaining the improvement by cold exposure of glucose tolerance and insulin action.

Vallerand, A.L., & Jacobs, I. (1990). **Influence of cold exposure on plasma triglyceride clearance in humans.** *Metabolism, 39* , 1211-1218.

Abstract Recent human studies have shown that cold exposure increases lipid oxidation, even when the oxidation of circulating free fatty acid (FFA) is markedly reduced by the ingestion of nicotinic acid, thus seriously questioning the importance of FFA for lipid oxidation in the cold-exposed humans. It was therefore hypothesized that similarly to prolonged exercise, fatty acid from plasma triglycerides (TG) are important energy substrates for oxidation during prolonged cold exposure in man. The goal of this study was to determine the influence of cold exposure on an index of plasma TG utilization, the intravenous fat tolerance test (IVFTT). To evaluate the possibility of a delayed increase in fat tolerance, a second cold exposure and a IVFTT were also performed 24 hours after the first cold exposure. Seven healthy males (fasting, seminude) were subjects to an IVFTT (1 mL/kg 10% lntralipid) on three occasions while resting for 160 minutes: (1) at 29°C. (2) in the cold (10°C, 1 m/s wind), and (3) at 10°C 24 hours after the first cold test. One week separated the warm test from the cold tests. Cold exposure reduced mean body temperature by 3.4 ± 0.1°C and increased energy expenditure 2.5 times in comparison to warm values ($P < .01$). It also increased fat oxidation by 70% ($P < .05$) and plasma glycerol levels ($P < .05$), but did not alter fat tolerance. Although the second cold test entailed essentially the same changes in body temperatures and heat production as the first one, the second cold test was accompanied by a further increase in fat utilization (132% above warm values, $P < .01$), slightly higher plasma glycerol levels, and an unchanged fat tolerance. The results of the present study demonstrate that cold exposure in humans significantly increases the oxidation of lipid, and that plasma TG do not appear to be an important energy substrate in the cold, even when lipid metabolism is further increased by the second cold test. It is suggested that adipose tissue TG and intramuscular TG, not plasma TG, are the preferred sources of fatty acids for oxidation in cold-exposed humans.

1991

Bain, B. (1991). ***Effectiveness of ice-vest cooling in prolonging work tolerance time during heavy exercise in the heat for personnel wearing Canadian Forces chemical defence ensembles.*** (DCIEM 91-06). Defence and Civil Institute of Environmental Medicine.

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Abstract The effectiveness of a portable, ice-pack cooling vest (Steelevest) in prolonging work tolerance time in chemical defence clothing in the heat (33°C dry bulb, 33% relative humidity or 25°C WBGT) was evaluated while subjects exercised at a metabolic rate of ~700 watts. Six male volunteers were used as subjects. The protocol consisted of a 20 minute treadmill walk at 1.33 $m \cdot s^{-1}$ (4.8 $km \cdot h^{-1}$) and 7.5% grade, followed by 15 minutes of a lifting task, 5 minutes rest, then another 20 minutes of lifting task for a total of one hour. The lifting task consisted of lifting a 20 kg box, carrying it 3 metres and setting it down. This was followed by a 6 metre walk (3 m back to the start point and 3 m back to the box) in 15 sec after which the lifting cycle began again. The work was classified as heavy as defined in a previous paper (McLellan et al (5)). This protocol was repeated until the subjects were unable to continue or they reached a physiological endpoint. The time to voluntary cessation or physiological endpoint was called the work tolerance time. Physiological endpoints were rectal temperature of 39°C, heart rate exceeding 95% of maximum for two consecutive minutes or visible loss of motor control or nausea.

The cooling vest had no effect on work tolerance time, rate of rise of rectal temperature or sweat loss. Work tolerance time without cooling averaged 39.6 ± 9.9 minutes compared with 44.3 ± 17.8 minutes with cooling (mean ± SD).

It was concluded that the Steelevest ice-vest is ineffective in prolonging work tolerance time and preventing increases in rectal temperature in the above conditions while wearing chemical protective clothing.

Bell, D. G., & Jacobs, I. (1991). *Blood lactate response to the CF EXPRES step test: final report.* (DCIEM 91-44). Defence and Civil Institute of Environmental Medicine.

Abstract This is the final report on the tasking to look at the blood lactate (LA) response to the Canadian Aerobic Fitness Test, i.e., EXPRES step test. The purposes of this study were to determine if LA could be used to predict maximal aerobic power ($\dot{V}O_2max$) from the EXPRES step-test procedures and to compare this prediction with the current procedures which employ submaximal heart rate (HR). Male (n=137) and female (n=98) CF personnel between the ages of 18 and 53 years participated in this study. The LA concentration after each stage of the step test was measured in all subjects by sampling blood from the finger-tip. A sub-sample of this population, 90 males and 66 females had their $\dot{V}O_2max$ measured directly during a maximal treadmill run. LA and heart rate (HR) from stage 5 were correlated with the treadmill-determined $\dot{V}O_2max$. At stage 5 the males ascend and descend a stairway consisting of 2 eight inch steps at a rate of 22 times per minute for 3 minutes; the females ascend and descend the same steps at 20 times per minute. The results showed increasing stages of the step test were associated with increasing LA. Correlations between LA and $\dot{V}O_2max$ were -0.71 and -0.72 for the males and females, respectively, and were higher than the correlations between HR and $\dot{V}O_2max$ which were -0.36 and -0.65 respectively. LA measured during stage 5 was a better predictor of $\dot{V}O_2max$ than heart rate for the males. For the females, although LA produced a higher correlation, it was not significantly different from HR. Age appears to be the main reason for the difference in LA response between males and females. Only 6% of the females tested were over 40 while 25% of the males exceeded this age.

Daanen, H. A. M., & Ducharme, M. B. (1991). ***Physiological responses of the human extremities to cold water immersion.*** (Rep.No. IZF 1991 A-15). TNO Institute for Perception.

Abstract Five subjects immersed their hands and feet twice during 1 hour sessions in a calorimeter bath, filled with water at 25°C. Before immersion, the hand (33.0±2.2°C) was warmer than the foot (30.6±2. 1°C) and so was the blood flow: respectively 5.8±5.2 versus 0.7±0.3 ml min^{-1}·100 ml tissue-I as determined by strain gauge plethysmography and 10.8±5.1 versus 6.7±5.3 by the doppler method. At the end of the immersion period the blood flow had decreased by a factor of 2.9 (doppler) and 4.3 (plethysmograph). The local heat transfer, determined by heat flux transducers, was higher immediately after immersion. The maximum was higher at the ventral sides than at the dorsal sides of the hand (225±93 versus 186±61 $W \cdot m^{-2}$) and the foot (178±53 versus 160±57 $W \cdot m^{-2}$). The total heat transferred to the water by hand and foot during the 60 minutes of immersion, determined by calorimetry, was 47± 21 and 36± 18 kJ respectively. The maximal heat flux was 37 ± 14 W for the hand and 34 ± 15 W for the foot. The local heat transfer, determined by the HFT, was highest immediately after immersion at the ventral side of the hand (225 ± 93 $W \bullet m^{-2}$), and lowest at the dorsal side of the foot (160 ± 57 $W \bullet m^{-2}$). The heat flux for the dorsal side of the hand was 186 ± 61 $W \bullet m^{-2}$ for the ventral side of the foot. Estimation of the total heat transfer from the extremity using the data from the two HFT's, showed lower values than the values obtained with calorimetry. Between the 20th and the 30th minute of immersion the average power transferred to the water, estimated from the HFT's, was calculated to be about 4.4 W, while the calorimeter measured a power transfer of 17.4 W. A very high heat flux from the fingers may explain part of the differences. Heat flux, rectal and local skin temperature and blood flow are very subject specific. One subject even transferred more heat to the water by the dorsal side of the hand than the ventral side. All subjects showed in some experiments fluctuations in heat flux and skin temperatures. These fluctuations may be associated with a thermoregulatory function.

Daanen, H. A. M., & Ducharme, M. B. (1991). **Physiological responses of the human extremities to cold water immersion.** *Arct. Med. Res., 50*(Suppl. 6), 115-121.

Abstract Five subjects immersed their hands and feet twice during 1 hour sessions in a calorimeter bath, filled with water at 25°C. Before immersion, the hand (33.0±2.2°C) was warmer than the foot (30.6±2. 1°C) and so was the blood flow: respectively 5.8±5.2 versus 0.7±0.3 ml min^{-1}·100 ml tissue-I as determined by strain gauge plethysmography and 10.8±5.1 versus 6.7±5.3 by the doppler method. At the end of the immersion period the blood flow had decreased by a factor of 2.9 (doppler) and 4.3 (plethysmograph). The local heat transfer, determined by heat flux transducers, was higher immediately after immersion. The maximum was higher at the ventral sides than at the dorsal sides of the hand (225±93 versus 186±61 $W \cdot m^{-2}$) and the foot (178±53 versus 160±57 $W \cdot m^{-2}$). The total heat transferred to the water by hand and foot during the 60 minutes of immersion, determined by calorimetry, was 47±21 and 36±36 kJ respectively and was not statistically different due to considerable interindividual differences. Interindividual differences were also found for heat flux, rectal and local skin temperatures and blood flow. These differences will have to be taken into account if a comparison is made between normal subjects and subjects having local cold injuries.

Ducharme, M. B. (1991). ***Individual variability of tissue temperature profile in the human forearm during water immersion.*** (DCIEM 90-10). Defence and Civil Institute of Environmental Medicine.

Abstract The purpose of the present study was to investigate the effect of a range of water temperatures (Tw from 15 to 36°C) on the shape of the tissue temperature profile of the resting human forearm at thermal stability. Tissue temperature (Tt) was continuously monitored by a calibrated multicouple probe during 3 hours immersion of the forearm. The probe was implanted approximately 9 cm distal from the olecranon process along the ulnar ridge. Tt was measured every 5 mm, from the longitudinal axis of the forearm (determined from computed tomography scanning) to the skin surface. For all temperature conditions, the temperature profile inside the limb was linear as a function of the radial distance from the forearm axis ($p < 0.01$) when the temperature data were averaged for the different groups at each water temperature tested. However, interindividual variability regarding the shape of the temperature profile was observed, in addition to intraindividual variability in 5 of the 15 subjects. A linear profile was observed in 50% of the subjects, a profile with convex curvature in 30%, and a profile with concave curvature in the remaining 20%. No significant relationship was observed between the occurrence rate of the different shapes of temperature profile and the water temperature. These data suggest that anatomical structures like bone and artery located at proximity to the pathway of the thermal probe implantation could have influenced the shape of the individual temperature profile inside the forearm.

Ducharme, M. B., & Frim, J. (1991). ***Methodology for calibration and use of heat flux transducers.*** (DCIEM 91-45). Defence and Civil Institute of Environmental Medicine.

Abstract The direct assessment of heat flux from the body is a basic measurement in thermal physiology. Heat flux transducers (HFTs) are being used increasingly for that purpose under different environmental conditions. However, questions have been raised regarding the accuracy of the manufacturer's constant of calibration, and also about the effect of the thermal resistance of the device on the true thermal flux from the skin. Two different types of waterproofed HFTs were checked for their calibration using the Rapid-k thermal conductivity instrument. A detailed description of the methodology used during the calibration is given. The mean differences between our calibration constants and the manufacturers' constants were $+20.2 \pm 7.1\%$ ($n = 15$) for Thermonetics Corporation's HFTs (San Diego, CA) and $-0.7 + 4.8\%$ ($n = 12$) for Concept Engineering's HFTs (Old Saybrook, CT). The highly significant statistical difference in the error of calibration between the two manufacturers ($p < 0.001$) becomes an important criterion for the selection of HFTs.

A model capable of simulating a large range of "tissue" insulation was used to study the effect of the underlying tissue insulation on the relative error in thermal flux due to the thermal resistance of the HFTs. The data show that the deviation from the true value of thermal flux increases with the reciprocal of the underlying tissue insulation ($r = 0.99$, $p < 0.001$). The underestimation of the heat flux through the skin measured by an HFT is minimal when the device is used on vasoconstricted skin in cool subjects (3 to 13% error), but becomes important when used on warm vasodilated subjects (29 to 35% error), and even more important on metallic skin mannequins (> 60% error). In order to optimize the accuracy of the heat flux measurements by HFTs, it is important to recalibrate the HFTs from Thermonetics Corporation, and to correct the heat flux values for the thermal resistance of the HFT when used on vasodilated tissues.

Ducharme, M. B., & Tikuisis, P. (1991). ***In vivo* thermal conductivity of the human forearm tissue during thermal stress.** *J. Appl. Physiol., 70*(6), 2682-2690.

Abstract The effective thermal conductivities of the skin + subcutaneous fat ($k_{eff\ skin + fat}$) and muscle ($k_{eff\ muscle}$) tissues of the human forearm at thermal steady state during immersion in water at temperatures (T_w) ranging from 15 to 36°C were determined. Tissue temperature (T_t) was continuously monitored by a calibrated multicouple probe during a 3-h immersion of the resting forearm. T_t was measured every 5 mm from the longitudinal axis of the forearm (determined from computed-tomography scanning) to the skin surface. Skin temperature (T_{sk}), heat loss (H_{sk}), and blood flow (Q) of the forearm, as well as rectal temperature (T_{re}) and arterial blood temperature at the brachial artery (T_{bla}), were measured during the experiments. When the k_{eff} values were calculated from the finite-element (FE) solution of the bioheat equation, $k_{eff\ skin + fat}$ ranged from 0.28 ± 0.03 to 0.73 ± 0.14 $W \cdot °C^{-1} \cdot m^{-1}$ and $k_{eff\ muscle}$ varied between 0.56 ± 0.05 and 1.91 ± 0.19 $W \cdot °C^{-1} \cdot m^{-1}$ from 15 to 36°C. The values of $k_{eff\ skin + fat}$ and $k_{eff\ muscle}$ calculated from the FE solution for $T_w \leq 30°C$, were not different from the average in vitro values obtained from the literature. The k_{eff} values of the forearm tissues were linearly related ($r = 0.80$, $P < 0.001$) to Q for $Tw \geq 30°C$. It was found that the muscle tissue could account for 92 ± 1% of the total forearm insulation during immersion in water between 15 and 36°C.

Ducharme, M. B., VanHelder, W. P., & Radomski, M. W. (1991). **Cyclic intramuscular temperature fluctuations in the human forearm during cold-water immersion.** *Eur. J. Appl. Physiol., 63,* 188-193.

Abstract The purpose of the present study was to investigate the intramuscular temperature fluctuations in the human forearm immersed in water at 15°C. Tissue temperature (Tt) was continuously monitored by a calibrated multicouple probe during 3 h immersion of the forearm. The probe was implanted approximately 90 mm distal from the olecranon process along the ulnar ridge. Tt was measured every 5 mm, from the longitudinal axis of the forearm (determined from computed tomography scanning) to the skin surface. Along with Tt, rectal temperature, skin temperature and heat loss of the forearm were measured during the immersions. Five of the six subjects tested showed evidence of cyclic temperature fluctuations in the forearm limited to the muscle tissue. The first increase of the muscle temperature was observed 75 (SE 6) min after the onset of the immersion, and the duration of the cycle averaged 36 (SE 3) min. The maximum increase of the muscle temperature, which ranged between 0.4°C and 1.0°C, was measured at the axis of the forearm, and was inversely correlated to the circumference of the subject's forearm ($P < 0.05$). No corresponding increases of the skin temperature and heat loss of the forearm were observed for the complete duration of the immersion. These data support the hypothesis of a significant contribution of the muscle vessels during cold-induced vasodilatation in the forearm.

Ducharme, M. B., VanHelder, W. P., & Radomski, M. W. (1991). **Tissue temperature profile in the human forearm during thermal stress at thermal stability.** *J. Appl. Physiol., 71*(5), 1973-1978.

Abstract The purpose of the present Study was to investigate the effect of a range of water temperature (Tw from 15 to 36°C) on the tissue temperature profile of the resting human forearm at thermal stability. Tissue temperature (Tti) was continuously monitored by a calibrated multicouple probe during 3 h of immersion of the forearm. The

probe was implanted ~9 cm distal from the olecranon process along the ulnar ridge. Tti was measured every 5 mm, from the longitudinal axis of the forearm (determined from computed tomography scanning) to the skin surface. Along with Tti, skin temperature (Tsk), rectal temperature (Tre), and blood flow were measured during the immersions. For all temperature conditions, the temperature profile inside the limb was linear as a function of the radial distance from the forearm axis ($P < 0.001$). Temperature gradient measured in the forearm ranged from 0.2 ± 0.1°C cm (Tw = 36°C) to 2.3 ± 0.5°C cm (Tw = 15°C). The maximal Tti was measured in all cases at the longitudinal axis of the forearm and was in all experimental conditions lower than Tre. On immersion at Tw < 36°C, the whole forearm can be considered to be part of the shell of the body. With these experimental data, mathematical equations were developed to predict, with an accuracy of at least 0.6°C, the Tti at any depth inside the forearm at steady state during thermal stress. The data of the present study support the important role of convective heat exchange between blood and tissue on the Tti of the forearm.

Frim, J., & Glass, K. (1991). ***Alleviation of thermal strain in engineering space personnel aboard CF ships with the Exotemp personal cooling system.*** (DCIEM 91-62). Defence and Civil Institute of Environmental Medicine.

Abstract The engineering spaces aboard Canadian Forces (CF) ships operating in warm climates can become very hot working environments. Some of these areas, notably the boiler room, are outside the citadel, and personnel working in these areas during periods of chemical threat must wear chemical defence (CD) clothing. The extra insulation and the increased resistance to sweat evaporation of this clothing, coupled with the heat of the environment, can impose a severe heat stress on the engineering personnel. A field trial was conducted aboard the HMCS Ottawa while en route from Halifax to Puerto Rico to see if the Exotemp liquid-based personal cooling system, proven very successful in CF Sea King helicopter operations in the Persian Gulf, could alleviate thermal stress under the above simulated conditions. Twelve engine room personnel from three watches participated in the trial, conducting their normal engine-room duties while being monitored for thermal physiological strain in four clothing ensembles: normal work dress (**WD**); normal work dress with cooling (**WC**); chemical defence clothing (**CD**); and chemical defence clothing with cooling (**CC**). Note that the engine room was used in place of the boiler room because it offered more space, and because the environment was easier to control. Heat stress conditions of 45-50°C dry-bulb temperature were created by shutting off the ventilation fans for about 90 minutes at the start of each watch. Rectal temperatures at 90 minutes of elapsed time clearly indicated statistically significant benefits of cooling with the chemical defence clothing (condition **CD**: 38.3°C; condition **CC**: 37.6°C; $p=0.002$). Although not statistically significant, reductions in core temperature were also seen when cooling was used with normal work dress (condition **WD**: 38.0°C; condition **WC**: 37.7°C; $p=0.053$). Heart rates were generally above 120 bpm without cooling (conditions **WD** and **CD**) while they generally remained below 120 bpm with cooling (conditions **WC** and **CC**). Limited skin temperature and heat flux information corroborated the core temperature and heart rate data, showing that the Exotemp personal cooling system can alleviate thermal strain in engineering space personnel. Personal cooling is recommended in conjunction with the CD ensemble, and could be considered for routine use with standard dress whenever ships are operating in hot climates.

Gass, G. C., McLellan, T. M., & Gass, E. M. (1991). **Effects of prolonged exercise at a similar percentage of maximal oxygen consumption in trained and untrained subjects.** *Eur. J. Appl. Physiol., 63,* 430-435.

Abstract Six trained male cyclists and six untrained but physically active men participated in this study to test the hypothesis that the use of percentage maximal oxygen consumption (% $\dot{V}O_2max$) as a normalizing independent variable is valid despite significant differences in the absolute $\dot{V}O_2max$ of trained and untrained subjects. The subjects underwent an exercise test to exhaustion on a cycle ergometer to determine $\dot{V}O_2max$ and lactate threshold. The subjects were grouped as trained (T) if their $\dot{V}O_2max$ exceeded 60 $ml \cdot kg^{-1} \cdot min^{-1}$, and untrained (UT) if their $\dot{V}O_2max$ was less than 50 $ml \cdot kg^{-1} \cdot min^{-1}$. The subjects were required to exercise on the ergometer for up to 40 min at power outputs that corresponded to approximately 50% and 70% $\dot{V}O_2max$ x. The allocation of each exercise session (50% or 70% $\dot{V}O_2max$) was random and each session was separated by at least 5 days. During these tests venous blood was taken 10 min before exercise (-10 min), just prior to the commencement of exercise (0 min), after 20 min of exercise (20 min), at the end of exercise and 10 min post-exercise (+10 min) and analysed for concentrations of cortisol, $[Na^+]$, $[K^+]$, $[Cl^-]$, glucose, free fatty acid, lactate $[la^-]$, [NH3], haemoglobin [Hb) and for packed cell volume. The oxygen consumption ($\dot{V}O_2$) and related variables were measured at two time intervals (14-15 and 34-35 min) during the prolonged exercise tests. Rectal temperature was measured throughout both exercise sessions. There was a significant interaction effect between the level of training and exercise time at 50% $\dot{V}O_2max$ for heart rate (f c)and venous $[la^-]$. At 70% $\dot{V}O_2max$, $\dot{V}O_2$ and ventilation (VE) for the T group and $\dot{V}O_2$, VE and carbon dioxide production for the UT group increased significantly with time and there was a significant interaction effect for fc, $[la^-]$, [Hb] and [NH3]. The change in body mass at 50% and 70% $\dot{V}O_2max$ was significantly greater in the T group. The present study found that when two groups of male subjects with different absolute $\dot{V}O_2max$ exercised at a similar percentage of $\dot{V}O_2max$ some effector responses were significantly different, questioning the validity of selecting % $\dot{V}O_2max$ as a normalizing independent variable.

Martineau, L., & Jacobs, I. (1991). **Effects of muscle glycogen and plasma FFA availability on human metabolic responses in cold water.** *J. Appl. Physiol., 71,* 1331-1339.

Abstract The purpose of this study was to investigate whether simultaneous alterations in the availability of plasma free fatty acids and muscle glycogen would impair the maintenance of thermal balance during cold water immersion in humans. Eight seminude subjects were immersed on two occasions in 18°C water for 90 min or until rectal temperature (T_{re}) decreased to 35.5°C. Each immersion followed 2.5 days of a specific dietary and exercise regimen designed to elicit low (LOW) or high glycogen levels (HIGH) in large skeletal muscle groups. Nicotinic acid (1.6 mg/kg) was administered for 2 h before and during immersion to inhibit white adipose tissue lipolysis. Biopsies from the vastus lateralis showed that the glycogen concentration before the immersion was significantly lower in LOW than in HIGH (223 ± 19 vs. 473 ± 24 mmol glucose units/kg dry muscle). However, the mean rates of glycogen utilization were not significantly different between trials (LOW 0.62 ± 0.14 vs. HIGH 0.88 ± 0.15 mmol glucose units · $kg^{-1} \cdot min^{-1}$). Nicotinic acid dramatically reduced plasma free fatty acid levels in both trials, averaging 127 ± 21 μmol/L immedi-

ately before the immersion. Cold water immersion did not significantly alter those levels. Plasma glucose levels were significantly reduced after cold water immersion to a similar extent in both trials (18 ± 4%). Mean respiratory exchange ratio at rest and during immersion was greater in HIGH than LOW, whereas there were no inter trial differences in O_2 uptake. The calculated average metabolic heat production during immersion tended to be lower (P = 0.054) in LOW than in HIGH (15.3 ± 1.9 vs. 17.5 ± 1.9 kJ/min). There were no intertrial differences between the immersion times (LOW 64 ± 9 vs. HIGH 71 ± 7 min), the total decrease of T_{re} or the overall rate of fall of T_{re}. These results suggest that, despite marked reductions in levels of energy substrates, the thermal and metabolic responses to cold remained unaltered, probably because of compensatory utilization of alternative fuels.

McLellan, T., Cheung, K., & Jacobs, I. (1991). **Incremental test protocol, recovery mode and the Individual Anaerobic Threshold.** *Int. J. Sports Med., 12,* 190-195.

Abstract The individual anaerobic threshold (IAT) is defined as the highest metabolic rate at which blood lactate (LA) concentrations are maintained at a steady-state during prolonged exercise (15). The purpose of this study was to compare the effects of active and passive recovery on the determination of IAT following both a submaximal or maximal incremental exercise test. Seven males ($\dot{V}O_2max$ = 57.6 1 ± 5.8 ml·kg^{-1}·min^{-1}) did two submaximal, incremental cycle exercise tests (30 W and 4 min per step) and two maximal incremental tests. Blood was sampled repeatedly during exercise and for 12 min during the subsequent recovery period, which was passive for one submaximal and one maximal test and active (~ 35% $\dot{V}O_2max$) during the other tests. An IAT metabolic rate and power output were calculated for the submax-passive (IATsp, LA = 1.85 ± 0.42 mmol·l^{-1}), maxpassive (IATmp, LA = 3.41 ± 1.14 mmol·l^{-1}), submax-active (IATsa, LA = 2.13 ± 0.45 mmol·l^{-1}) and max-active (IATma, LA = 3.44 ± 0.73 mmol·l^{-1}) protocols. At weekly intervals, the subjects exercised for 30 min at one of the four IAT metabolic rates. Active recovery did not affect the calculation of IAT, but following the maximal incremental tests, IAT occurred at a higher ($p < 0.05$) power output, absolute $\dot{V}O_2$ and % $\dot{V}O_2max$ (71% $\dot{V}O_2max$) compared with the IAT determined with the submaximal incremental tests (61% $\dot{V}O_2max$). During the 30-min IATmp and IATma rides, LA and pH did not change significantly during the final 15 min, but LA values were higher (4.65 ± 0.62 and 5.20 ± 1.30, respectively) and pH lower (7.31 ± 0.02 and 7.30 ± 0.06, respectively) compared with the IATsp and IATsa rides (2.40 ± 0.77 and 2.90 ± 0.78, respectively for LA and 7.36 ± 0.03 and 7.35 ± 0.03, respectively for pH). The results demonstrate that for these subjects the calculated IAT is not affected by an active recovery period but the IAT occurred at a higher metabolic rate following a maximal compared with a submaximal incremental exercise test.

McLellan, T. M. (1991). ***Influence of metabolic rate at 40° C ambient temperature on work tolerance times with varying levels of Canadian Forces NBC protective clothing.*** (DCIEM 91-27). Defence and Civil Institute of Environmental Medicine.

Abstract This study examined the effects of a warm environmental temperature (40°C and 50% relative humidity) and metabolic rate on soldiers' work tolerance time (WTT) while wearing various levels of nuclear, biological and chemical (NBC) defence protective clothing. Nineteen unacclimatized males (31 ± 6 y, 80 ± 11 kg, 1.76 ± 0.04 m) were assigned to exercise at either a light intermittent (LI) (N = 4), light continuous (LC) (N = 5), moderate continuous (MC) (N =

5) or heavy continuous (HC) (N = 5) metabolic rate. For groups LI and LC exercise involved walking on a treadmill at 4 $km \cdot h^{-1}$ with a 0% grade and lifting 10 kg boxes. Group MC walked at 4.8 $km \cdot h^{-1}$ with a 3% grade and lifted 15 kg boxes. Group HC walked at 4.8 $km \cdot h^{-1}$ with a 7.5% grade and lifted 20 kg. Subjects were tested wearing three levels of clothing protection: combat clothing (Low); combats and a semi-permeable NBC overgarment (Med); combats and NBC overgarment, gloves, boots and respirator (High). WTT was the time until rectal temperature (Tre) reached 39.3°C, heart rate reached 95% maximum, dizziness or nausea precluded further exercise, or 5 h had elapsed. For group LI, WTT was similar for the low (137 ± 15 min) and medium (117 ± 9 min) levels of protection. WTT was significantly reduced for High (67 ± 6 min) and Tre in 1.7 ± 0.2°C·h^{-1}. For group LC, WTT was greater for Low (91 ± 11 min, Tre increased 1.4 ± 0.4°C·h^{-1}) compared with either the medium (68 ± 7 min, Tre increased 1.7 ± 0.3°C·h^{-1}) or high (55 ± 2 min, Tre increased 2.0 ± 0.4°C·h^{-1}) levels of protection. For group MC, WTT was greater for Low (51 ± 5 min, Tre increased 1.9 ± 0.2°C·h^{-1}) compared with High (35 ± 2 min, Tre increased 2.5 ± 0.2°C·h^{-1}) but WTT for both of these levels of protective clothing were not different from Med (44 ± 2 min, Tre increased 2.5 ± 0.50°C·h^{-1}). Finally, for group HC, WTT was significantly reduced from Low (43 ± 6 min, Tre increased 2.4 ± 0.4°C·h^{-1}) to Med (32 ± 6 min, Tre increased 2.6 ± 0.3°C·h^{-1}) and to High (25 ± 3 min, Tre increased 3.0 ± 0.2°C·h^{-1}). The logarithm of WTT was directly proportional to the average metabolic rate ($\dot{V}O_2$ (mL·kg^{-1},min^{-1})) for Low (Log(WTT) = 2.403 - 0.0365·$\dot{V}O_2$, r = 0.90), Med (Log(WTT) = 2.282 - 0.0318·$\dot{V}O_2$, r = 0.89) and High (Log(WTT) = 2.191 0.0310·$\dot{V}O_2$, r = 0.95). If the metabolic rate of a task is known, these relationships can be used to calculate work to rest schedules that may prolong work time in the three levels of NBC protective clothing at 40°C and 50% relative humidity.

McLellan, T. M. (1991). **The influence of respiratory acidosis on the exercise blood lactate response.** *Eur. J. Appl. Physiol., 63,* 6-11.

Abstract The purpose of the present study was to examine the influence of a respiratory acidosis on the blood lactate (La) threshold and specific blood La concentrations measured during a progressive incremental exercise test. Seven males performed three step-incremental exercise tests (20 W·min^{-1}) breathing the following gas mixtures; 21% O2 balance-nitrogen, and 21% O2, 4% CO2 balance-nitrogen or balance-helium. The log-log transformation of La oxygen consumption ($\dot{V}O_2$) relationship and a 1 mmol·l^{-1} increase above resting values were used to determine a La threshold. Also, the $\dot{V}O_2$, corresponding to a La value of 2 (La2) and 4 (La4) mmol·l^{-1} was determined. Breathing the hypercapnic gas mixtures significantly increased the resting partial pressure of carbon dioxide (P CO2) from 5.6 kPa (42 mmHg) to 6.1 kPa (46 mmHg) and decreased pH from 7.395 to 7.366. During the incremental exercise test, P CO2 increased significantly to 7.2 kPa (54 mmHg) and 6.8 kPa (51 mmHg) for the hypercapnic gas mixtures with nitrogen and helium, respectively, and pH decreased to 7.194 and 7.208. In contrast, blood P CO2 decreased to 4.9 kPa (37 mmHg) at the end of the normocapnic exercise test and pH decreased to 7.291. A blood La threshold determined from a log-log transformation [1.20 (0.28) 1·min^{-1}] or as an increase of 1 mmol·l^{-1} [1.84 (0.46) 1·min^{-1}] was unaffected by the acid-base alterations. Similarly, the $\dot{V}O_2$, corresponding to La2 and La4 was not affected by breathing the hypercapnic gas mixtures [2.12 (0.46) 1·min^{-1} and 2.81 (0.52) 1·min^{-1}, respectively]. Blood La values were reduced significantly at max-

imal exercise while breathing the hypercapnic gas mixtures (5.72 ± 1.34 mmol·l^{-1}) compared with the normocapnic test (6.96 ± 1.14 mmol·l^{-1}). It is concluded that respiratory-induced acid-base manipulations due to the inspiration of 4% CO2, have a negligible influence on the blood La response during a progressive exercise test at low and moderate power outputs. Lower blood La values are observed at maximal exercise with an induced respiratory acidosis but this negative influence is less than what has been reported for an induced metabolic acidosis.

McLellan, T. M., & Jacobs, I. (1991). **Muscle glycogen utilization and the expression of the relative exercise intensity**. *Int. J. Sports Med., 12*, 21-26.

Abstract Previous research has shown that the rate of muscle glycogen utilization is related to exercise intensity expressed relative to maximal aerobic power ($\%\dot{V}O_2$ max). The purpose of this study was to compare the relationship between glycogen utilization and $\%\dot{V}O_2$ max to that between glycogen utilization and intensity expressed relative to the onset of blood lactate accumulation (%OBLA) during cycle exercise. It was hypothesized that the rate of glycogen utilization would be related more closely to intensity expressed as %OBLA than to intensity expressed as $\%\dot{V}O_2$ max. Nineteen subjects (15 males and 4 females) performed two separate tests to determine $\dot{V}O_2$ max and OBLA during continuous incremental exercise. On a third occasion biopsies were taken from the m. vastus lateralis before and after 30 min of exercise at randomly assigned intensities ranging from 50-80% $\dot{V}O_2$ max, corresponding to 67-117% OBLA. There was a large inter-subject variation in aerobic fitness with $\dot{V}O_2$ max ranging from 34 to 66 mL·kg^{-1}·min^{-1} and OBLA ranging from 64-84% $\dot{V}O_2$ max. Absolute $\dot{V}O_2$ max. and the $\dot{V}O_2$ at OBLA were correlated strongly (r = 0.90). The change in glycogen concentration during the 30-min exercise bout ranged from an increase of 58 to a depletion of 200 mmol glucose units·kg^{-1} dry muscle weight. Neither absolute nor relative glycogen utilization was significantly related to the exercise intensity expressed as either $\%\dot{V}O_2$ max or %OBLA. Stepwise multiple regression was used to identify variables which could account for the variation in glycogen depletion. From among indicators of aerobic fitness ($\dot{V}O_2$ max, OBLA) and exercise intensity ($\%\dot{V}O_2$ max, %OBLA, absolute $\dot{V}O_2$ during exercise), $\dot{V}O_2$ max (mL·kg^{-1}·min^{-1}) was the only variable which accounted for a significant amount of the intersubject variation in glycogen depletion (r = –0.56). The hypothesis was not accepted and the results suggest that the extent of muscle glycogen depletion among subjects of different sex and varied fitness levels cannot be predicted accurately from the relative expression of exercise intensity.

McLellan, T. M., Meunier, P., & Livingstone, S. (1991). ***Influence of a new vapour protective clothing layer on physical work tolerance times at 40 deg C ambient temperature.*** (DCIEM 91-35). Defence and Civil Institute of Environmental Medicine.

Abstract A new vapour protective clothing ensemble is under development at the Defence Research Establishment Ottawa. This clothing is thinner and more close-fitting to the body than the present nuclear, biological and chemical (NBC) protective garment. The purpose of the present study was to examine the influence of this new vapour protective clothing on physical work performance in a hot environment (40°C and 25% relative humidity). Eleven unacclimatized males (28 ± 6 y, 79 ± 8 kg, 1.76 ± 0.06 m) were assigned to exercise at either a

light intermittent (L) (N = 6), or heavy continuous (H) (N = 5) metabolic rate. Group L alternated between 15 min of walking on a treadmill at 1.11 $m \cdot s^{-1}$ with a 0% grade and 15 min of rest. Group H walked continuously at 1.33 $m \cdot s^{-1}$ with a 3% grade. Subjects were tested wearing three clothing configurations: full NBC protection (TOPP High) with the combat clothing worn under the NBC garment (TH + CC); full NBC protection without combat clothing (TH - CC); the new vapour protective clothing together with the NBC gloves, boots and respirator (NPC). WTT was the time-period until rectal temperature (Tre) reached 39.3°C, heart rate reached 95% maximum, dizziness or nausea precluded further exercise, or 3 h had elapsed. For group L, WTT was similar for TH + CC (113 ± 12 min) and TH - CC (139 ± 18 min). WTT was significantly increased for NPC where all subjects completed the 3 h in the climatic chamber. The rate of increase for Tre was significantly reduced for NPC (0.3 ± 0.1°C·h^{-1}) compared with both TH + CC (0.9 ± 0.1°C·h^{-1}) and TH - CC (0.8 ± 0.2°C·h^{-1}). The evaporative efficiency of the new clothing ensemble (76 ± 4%) was also significantly increased compared with both TH + CC (36 ± 17%) and TH - CC (46 ± 9%). For group H, WTT significantly increased from TH + CC (46 ± 15 min) to TH - CC (60 ± 21 min) and to NPC (85 ± 28 min). The rate of increase in Tre was not different among the three clothing configurations. Evaporative efficiency was significantly different among the three clothing trials (19 ± 8%, 34 ± 4% and 57 ± 7% for TH + CC, TH - CC and NPC, respectively). For both groups, mean skin temperature and heart rates reflected the differences in the evaporative efficiency of the clothing comparisons. The results of this experiment clearly show the benefits of the new vapour protective clothing on physical work performance in a hot environment. Also, the data strongly suggest that, if possible, the combat clothing should not be worn under the present NBC garment.

Tikuisis, P., Bell, D. G., & Jacobs, I. (1991). **Shivering onset, metabolic response, and convective heat transfer during cold air exposure.** *J. Appl. Physiol., 70,* 1996-2002.

Abstract The onset and intensity of shivering of various muscles during cold air exposure are quantified and related to increases in metabolic rate and convective heat loss. Thirteen male subjects resting in a supine position and wearing only shorts were exposed to 10°C air (42% relative humidity and <0.4 m/s airflow) for 2 h. Measurements included surface electromyogram recordings at six muscle sites representing the trunk and limb regions of one side of the body, temperatures and heat fluxes at the same contralateral sites, and metabolic rate. The subjects were grouped according to lean (LEAN, n = 6) and average body fat (NORM, n = 7) content. While the rectal temperatures fluctuated slightly but not significantly during exposure, the skin temperatures decreased greatly, more at the limb sites than at the trunk sites. Muscles of the trunk region began to shiver sooner and at a higher intensity than those of the limbs. The intensity of shivering and its increase over time of exposure were consistent with the increase in the convective heat transfer coefficient calculated from skin temperatures and heat fluxes. Both the onset of shivering and the magnitude of the increase in metabolic rate due to shivering were higher for the LEAN group than for the NORM group. A regression analysis indicates that, for a given decrease in mean skin temperature, the increase in metabolic rate due to shivering is attenuated by the square root of percent body fat. Thus the LEAN group shivered at higher intensity, resulting in higher increases in metabolic heat production and convective heat loss during cold air exposure than did the NORM group.

Tikuisis, P., & Ducharme, M. B. (1991). **Finite-element solution of thermal conductivity of muscle during cold water immersion.** *J. Appl. Physiol., 70,* 2673-2681.

Abstract The in vivo or effective thermal conductivity (keff) of muscle tissue of the human forearm was determined through a finite-element (FE) model solution of the bioheat equation. Data were obtained from steady state temperatures measured in the forearm after 3 h of immersion in water at temperatures (Tw) of 15 (n = 6), 20 (n = 5), an 30°C (n = 5). Temperatures were measured every 0.5 cm from the longitudinal axis of the forearm to the skin ~ 9 cm distal from the elbow. Heat flux was measured at two sites on the skin adjacent to the temperature probe. The FE model is comprised of concentric annular compartments with boundaries defined by the location of temperature measurements. Through this approach, it was possible to include both the metabolic heat production and the convective heat transfer between blood and tissue at two levels of blood flow, one perfusing the compartment and the other passing through the compartment. Without heat exchange at the passing blood flow level, the arterial blood temperature would be assumed to have a constant value everywhere in the forearm muscles, leading to a solution of the bioheat equation that greatly underpredicts keff. The extent of convective heat exchange at the passing blood flow level is estimated to be ~60% of the total heat exchange between blood and tissue. Concurrent with this heat exchange is a decrease in the temperature of the arterial blood as it flows radially from the axis to the skin of the forearm, and this decrease is enhanced with a lowered Tw. The mean calculated value of keff for muscle was 0.556 $W \cdot m^{-1} \cdot °C^{-1}$, with no significant difference either among Tw values tested or among regions within the forearm. Most of the heat loss from the forearm is determined to be convective heat transfer from the blood to the tissue, which decreases in magnitude with increasing Tw (95.0, 91.6, and 77.3% of the total beat loss for immersions at Tw = 15, 20, and 30°C, respectively).

Tikuisis, P., McCracken, D., & Radomski, M. W. (1991). **Heat debt during cold air exposure before and after cold water immersions.** *J. Appl. Physiol., 71*(1), 60-68.

Abstract Acclimation to cold can manifest itself in several different ways, insulative and metabolic being the most common. Bittel (J. Appl. Physiol. 62: 1627-1634, 1987) has demonstrated that heat debt, which encompasses both heat production and heat loss, can be used as a unitary index of acclimation. However, conflicting results are obtained if heat debt is calculated using a mean-weighted body temperature (Tb) vs. the change of body heat content through the integration of heat storage (S). The present study examines the determination of heat debt by three methods of calculation, the first based on and the other two based on S where heat losses are measured in one and predicted in the other. Data were obtained from five healthy young males exposed to 10°C air for 2 h on four different occasions. The fast two exposures provided control data, while the last two were performed after 5 and 10 days, respectively, of daily immersions in 15°C water to induce acclimation. The variability in response between the control exposures was as large as that among the other exposures. Although the method of calculation using Tb indicated that subjects were close to a thermal balance after 2 h of cold air exposure, this contrasted sharply with the result of the other two methods that indicated heat debt was still increasing steadily. The latter two methods are considered more' accurate for transient heat debt calculation. Although cases of individual acclimation were found, these were different among the subjects, resulting in pooled responses that indicated no group acclimation by means of any of the three methods of calculation. It is then demonstrated that conditions exist where no change in heat debt can

mask actual changes in insulation and metabolism. Two recommendations that emerge from this study are that 1) the integration of S should be used to calculate heat debt for non-steady-state conditions and 2) heat debt should not be used as the only index of acclimation.

Vallerand, A. L., Michas, R. D., Frim, J., & Ackles, K. N. (1991). **Heat balance of subjects wearing protective clothing with a liquid- or air-cooled vest.** *Aviat. Space Environ. Med., 62,* 383-391.

Abstract The goals of this study were, first, to determine the extent of the heat strain induced by wearing the Canadian Forces (CF) aircrew chemical defence individual protection ensemble (CD IPE) under simulated hot cockpit conditions, and second, to determine the effectiveness of a liquid-cooled (LC) and an air-cooled (AC) vest in relieving such heat strain. Seven (7) healthy male subjects were subjected to three heat exposures (37°C, 50% r.h., for 150 min, time-weighted metabolic rate of about 240 W, 1 week apart) either with no cooling (NC), LC or AC vests. NC was only tolerated for 95 ± 5 min, whereas all subjects completed the 150-min tests with AC or LC ($p < 0.01$). The large rate of increase in rectal temperature (T_{re}) during NC (1.00 ± 0.05°C/h) was attenuated by 51% with LC and by an even greater amount with AC (64%, $p < 0.01$). NC entailed a sweat rate of almost 1 kg/h, which was reduced 38% by LC and 51% by AC ($p <$ 0.0 1). The combined dry and evaporative heat losses H_{EKC} of LC and AC vests were significantly greater than that of NC (164 ± 7 and 181 ± 9 vs. 124 ± 9 W, respectively; $p <$ 0.01). The results demonstrate that subjects wearing CF aircrew IPE under simulated hot cockpit conditions can only tolerate 95 min of the 150-min test, and experience significant heat strain. In contrast, this heat strain is significantly alleviated by either cooling vest, although greater improvements in T_{re} sweat rate, heart rate, evaporative efficiency index, and thermal comfort were observed with AC, possibly the result of its slightly greater total cooling and three times higher evaporative cooling.

1992

Bain, B., Jacobs, I., & Buick, F. (1992). **Effect of simulated air combat maneuvering on muscle glycogen and lactate.** *Aviat. Space Environ. Med., 63,* 505-509.

Abstract Muscle glycogen and muscle and blood lactate were evaluated before and after a +4.0/7.0 Gz simulated air combat maneuvering (SACM) protocol in the human centrifuge. The subjects were 8 healthy males, age 25-43 y. Muscle glycogen and lactate were determined from biopsies of m. vastus lateralis in 6 subjects and whole blood lactate was analyzed in finger-tip blood samples from 8 subjects. G-tolerance time was 256 ± 33 s (Mean ± SEM). The decrease in glycogen concentration averaged 81 ± 36 mmol • kg^{-1} dry wt. ($p=0.07$). The rate of glycogen utilization was low, averaging 0.4 ± 0.1 mmol • kg^{-1} • s^{-1}. Muscle lactate increased significantly from 28 ± 2 mmol • kg^{-1} dry wt pre-SACM to 51 ± 4 mmol • kg^{-1} post-SACM. Post-SACM blood lactate was 4.2 ± 0.3 mmol • L^{-1}. Neither final blood nor muscle lactate values nor the difference between pre and post SACM muscle lactate concentrations were related to G-tolerance time. It was concluded that glycogen availability in m. vastus lateralis is not a limiting factor during exposure to headward acceleration of this type and duration. The lactate values, while high, cannot fully explain the muscular fatigue occurring during centrifuge exposures of the type used here. Therefore, the suggestion by others that anaerobic energy metabolism in skeletal muscles is the crucial factor limiting the ability to resist fatigue during exposure SACM is not supported and is likely an oversimplification of a much more complex problem.

Bain, B., Smith, A. W., & Plyley, M. J. (1992). **Effect of varying rest intervals between repeated submaximal isometric contractions on endurance time, EMG power spectrum and signal amplitude.** *Eur. J. Appl. Physiol., (submitted for publication).*

Abstract Nine subjects performed two submaximal (50% MVC) isometric contractions to fatigue with the quadriceps muscle. Rest periods of 1, 5, 10 and 30 minutes intervened between the contractions and only-one set of contractions was performed on a given day. EMG was monitored and recorded from the vastus lateralis muscle. Force was monitored using a force transducer and time to fatigue recorded. Mean and -median frequency and average, rectified amplitude of the EMG signal (AEMG) calculated from the first, middle and last 5 seconds of each record.

The different rest intervals did not change the response of the mean or median frequency or the absolute response of normalized AEMG during the second contraction, however, the rate of change of AEMG was significantly increased during contraction 2 compared to contraction one for the 1 and 5 minute rest intervals. Endurance time was significantly reduced for the second contraction for the one, five and ten minute rest intervals.

In summary, varying the length of a rest interval between two, submaximal isometric contractions using the quadriceps muscle, had no effect on the response of mean or median frequency or normalized, average EMG amplitude. There was an effect on the rate of change of AEMG, however. The results of this study suggest that changes in conventional EMG amplitude and frequency parameters may not always adequately reflect physiological changes during muscular exercise. Examining the rate of change of these variables may prove more informative.

Bain, B., & Vallerand, A. L. (1992). **Limb blood flow and aircrew CD ensembles in the heat with and without cooling.** *Aviat. Space Environ. Med., 63*(4), 267-272.

Abstract The effect of auxillary air cooling on endurance time and limb blood flow in the heat (37°C, 50% r.h., target time = 150 min) while wearing aircrew chemical defense (CD) ensembles was examined. Eight males were dressed in aircrew CD ensembles with or without an air-cooled vest. After an initial 10 min treadmill walk and 20 min of seated rest, the subjects alternately rested and exercised on a cycle ergometer (10 min rest, 10 min exercise) resulting in an overall metabolic rate of 240 W. Arm and leg blood flow (ABF, LBF), determined by venous accluion plethysmography, were significantly lower with air cooling (AC) than with no cooling (NC) during the same time period ($p < 0.05$). Endurance time was much greater with AC than with NC (150 min AC vs. 92 ± 0.08 min NC, $p < 0.01$). Arm and calf skin temperatures, rectal temperature and heart rate were all significantly lower with AC than with NC ($p < 0.05$) after the onset of the cycle exercise. The results show that the use of the air-cooled vest under these conditions was able to increase heat tolerance and reduce blood flow to the periphery.

Bell, D. G., & Jacobs, I. (1992). **Blood lactate response to the Canadian Aerobic Fitness Test in Females.** *Can. J. Spt. Sci., 17,* 148-151.

Abstract This study evaluated the blood lactate (LA) response to the Canadian Aerobic Fitness Test (CAFT) in female subjects and compared the strength of prediction of $\dot{V}O_2$ max determined by LA and heart rate (HR). The sample was 98 Canadian Forces females between the ages of 18 and 45 years. The LA concentration after each stage of the step test was measured in all subjects by sampling blood from the finger-tip. $\dot{V}O_2$ max was measured directly during a maximal treadmill run in 66 of these subjects.

The results showed that increasing stages of the step test were associated with increasing LA. The correlation between LA after stage 5 of the step test and the directly determined $\dot{V}O_2$ max was r=-0.72, and was not significantly different from the correlation between HR and $\dot{V}O_2$ max (r=-0.66). The relationship between LA and $\dot{V}O_2$ max for these females was similar to the relationship established earlier for males; however, the correlation between HR and $\dot{V}O_2$ max for the females was different than that observed in the males. The present data for the females suggest that LA and HR after stage 5 of the CAFT predict $\dot{V}O_2$ max equally well for females under age 40.

Bell, D. G., & Jacobs, I. (1992). **Velocity specificity of training in body builders.** *Can. J. Spt. Sci., 17*(1), 28-33.

Abstract This study investigated the effects of many years of body building on muscular strength and endurance. Eight bodybuilders (BB), four males and four females, and eight controls (C), four males and four females, performed a muscle fatigue test (MFT) consisting of 25 maximal leg extensions at angular velocities of 180°/s and 300°/s. The results showed for strength that at both the slow and fast contraction speeds BB were significantly stronger than C and males were significantly stronger than the females. For muscular endurance the results showed at the slow contraction speed that the torques and the torque decline were greater in the BB than the C and greater in the males than the females. At the faster contraction speed torque decline was similar in all groups, while torques for the BB and male-C were similar and significantly greater than the torques for the female-C. The ratio of torques (fast/slow) for both strength and muscular endurance showed a main effect due to training status which supported the velocity specificity hypothesis. However, when the relative torques over the 25 contractions at both speeds were looked at no velocity specificity occurred for muscular endurance. The data suggest a definite velocity specificity for the strength factor in BB; whereas, the same conclusion is not as clear for the muscular endurance factor.

Bell, D. G., Lee, S. W., & Jacobs, I. (1992). **Blood lactate response to the Canadian Aerobic Fitness Test (CAFT).** *Can. J. Spt. Sci., 17*(1), 14-18.

Abstract This study evaluated the blood lactate (LA) response to stepping exercise, specifically the CAFT. It also compared the ability of lactate (LA) and heart rate (HR) at a given stage of the step test to predict directly measured $\dot{V}O_2$ max. 137 male CF personnel between the ages of 18 and 53 years participated in this study. The LA concentration after each stage of the CAFT was measured in all subjects by sampling blood from the finger-tip. 78 of these subjects also had their $\dot{V}O_2$ max measured directly during a maximal treadmill run. The analysis showed that increasing stages of the CAFT were associated with exponentially increasing LA. When the LA and HR measures at stage five of the step test were compared for their ability to predict $\dot{V}O_2$ max, the correlation between lactate and $\dot{V}O_2$ max was –0.71 ($p<.001$), between HR and $\dot{V}O_2$ max it was –0.36 ($p<.01$). At stage 5, [LA] ranged from 1.0 to 6.9, with a mean of 2.6 $mmol^{-1}$. These results suggest that during stage 5 of the CAFT, LA is a better predictor of $\dot{V}O_2$ max than HR.

Bell, D. G., Tikuisis, P., & Jacobs, I. (1992). **Relative intensity of muscular contraction during shivering.** *J. Appl. Physiol., 72*, 2336-2342.

Abstract The intensity of cold-induced shivering, quantified by surface electromyography (EMG) and then expressed as a function of the maximal myoelectrical activity (IEMG) obtained during a maximum voluntary contraction (MVC), was examined in this study in individuals classified by body fat. In addition the relationship between shivering and metabolic rate (MR), and the relative contribution of various muscle groups to total heat production were studied. Ten semi-nude male volunteers, 5 LEAN, less than 11% body fat, and 5 NORM, greater than 15% body fat, were exposed to 10°C air for 2 h. EMG of six muscle groups, the pectoralis major (PE), rectus abdominus (AB), rectus femoris (FE), gastrocnemius (GA), biceps brachii (BI) and brachioradialis (BR) was measured and compared with the EMG of each muscle's MVC. A whole body index of shivering (SUM), determined from the mass-weighted intensity of shivering of each muscle group, was correlated with MR. After the initial few minutes of exposure only the PE, FE, and BI continued to increase their intensity of shivering. Shivering intensity was higher in the central muscles ranging from 5 to 16% of MVC compared with the peripheral muscles which ranged from 1 to 4% of MVC. Shivering intensities were similar in the peripheral muscles for the LEAN and NORM groups, while differences occurred in the trunk muscles for the PE and AB. SUM correlated significantly with each individual's increase in MR (r = 0.63 to 0.97). It was further estimated that 71% of the heat production originated from the central muscles of the trunk followed by 21% attributed to the FE while the smaller muscle masses of the upper limbs and lower leg contributed the remaining 8%. The results suggest that the observed pattern and intensity of shivering minimizes heat loss and optimizes heat production during cold exposure.

Ducharme, M. B. (1992). ***Testing of the Cocoon-4 sleeping shelter.*** (DCIEM 92-45). Defence and Civil Institute of Environmental Medicine.

Abstract The objective of the present study was to evaluate the performance of a new concept of sleeping shelter, the Cocoon-4, in the field and in the laboratory, and under different temperature and humidity conditions that could be encountered by the Canadian Forces. It was found that the concept of adding air to an airtight down sleeping shelter to vary the insulation while keeping the down dry works well. Some problems with the quality of construction and the design of some critical components such as the valves were observed which made the performance of the Cocoon-4 less impressive than expected from the claims made by the manufacturer. It was concluded that the Cocoon-4 could be useful for the Canadian Forces as emergency shelter providing the manufacturer could improve on the quality of his product, and could add some modifications to the design.

Ducharme, M. B., & Frim, J. (1992). **Errors associated with the use of heat flow transducers.** In R. Y. Nishi (Ed.), *Proceedings of the DCIEM Diver Thermal Protection Workshop, 31 Jan - 2 Feb 1989,* DCIEM No. 92-10, (pp. 213-217). North York, Ontario: Defence and Civil Institute of Environmental Medicine.

Abstract The direct assessment of heat flux from the body is a basic measurement in thermal physiology. Heat flux transducers (HFTs) are being used increasingly for that purpose under different environmental conditions. However, questions have been raised regarding the accuracy of the manufacturer's constant of calibration, and also about the effect of the thermal resistance of the device on the true thermal flux from the skin. Two different types of waterproofed HFTs were checked for their calibration using the

Rapid-K heat flow meter conductivity instrument. The mean difference between the re calibrations and the manufacturer's constants is +20.2±7.1% (n=15) for Thermonetics Corporation's HFTs (San Diego, CA), and -0.7±4.8% (n=12) for Concept Engineering's HFTs (Old Saybrook, CT). The significant difference in the error of calibration between the two manufacturers ($p<0.001$) becomes an important criterion for the selection of HFTs. A model capable of simulating a large range of insulation values (variable-R model) was used in order to study the effect of the underlying tissue insulation on the relative error in thermal flux due to the thermal resistance of the HFTs. The data show that the deviation from the true value of thermal flux increases with the reciprocal of the underlying tissue insulation ($r=0.99$, $p<0.001$). The underestimation of the heat flux through the skin measured by a HFT is minimum when the device is used on vasoconstricted skin in cool subjects (3 to 13% error), but becomes important when used on warm vasodilated subjects (28 to 42% error), and even more important on metallic skin mannequins (>60% error). In order to optimize the accuracy of the heat flow measurements by heat flux transducers, it is important to recalibrate the HFTs from Thermonetics Corporation and to correct the heat flux values for the thermal resistance of the HFT when used on vasodilated tissue.

Ducharme, M. B., & Tikuisis., P. (1992). **Forearm temperature profile during the transient phase of thermal stress.** *Eur. J. Appl. Physiol., 64,* 395-401.

Abstract The transient temperature response of the resting human forearm immersed in water at temperatures (Tw) ranging from 15 to 36°C was investigated. Tissue temperature (Tt) was continuously monitored by a calibrated multicouple probe during the 3 h-immersions. Tt was measured every 5 mm, from the longitudinal axis of the forearm to the skin surface. Skin temperature (Tsk), rectal temperature (Tre), and blood flow (Q) were also measured during the immersions. The maximum rate of change of the forearm mean tissue temperature (Ttmax) occurred during the first 5 min of the immersion. Ttmax was linearly dependent on Tw ($p < 0.001$), ranging from $-0.8 \pm 0.1°C \cdot min^{-1}$ at 15°C to $0.2 \pm 0.1°C \cdot min^{-1}$ at 36°C. The maximum rate of change of compartment mean temperature (Ttmax) was dependent ($p < 0.001$) on the radial distance from the longitudinal axis of the forearm. The half-time for thermal steady-state of the forearm mean tissue temperature (Ti1/2) was linearly dependent on Tw between 30 and 36°C ($p < 0.01$), ranging from 15.6 ± 0.6 min at 30°C to 9.7 ± 1.2 min at 36°C and not different between 15 and 30°C, averaging 16.2 ± 0.6 min. There was a significant linear relationship between the half-time for thermal steady-state of the compartment mean temperature (Ti1/2) and the radial distance from the longitudinal axis of the forearm for each water condition tested ($p < 0.001$). The data of the present study suggest that the forearm blood flow is an important determinant of the transient thermal response of the forearm tissue during thermal stress.

Frim, J., Heslegrave, R., Bossi, L., & Popplow, J. (1992). **Thermal strain in F-18 pilots during sustained chemical defence operations.** In W. A. Lotens & G. Havenith. (Ed.), *Proceedings of the 5th International Conference on Environmental Ergonomics,* (pp. 96-97). Maastricht, The Netherlands: TNO Institute for Perception.

Abstract Chemical defence (CD) garments add insulation to the body and interfere with heat dissipation. This, combined with possible environmental stress in a cockpit, can lead to unacceptable levels of thermal strain in aircrew. The present study was undertaken to evaluate thermal physiological strain in F-18 pilots during CD operations in warm weather. Three primary pilots dressed in CD garments and 3 safety pilots

dressed in standard (STD) clothing flew 7 missions over 3 days; during the next week they reversed roles. Portable physiological monitors were used to record rectal temperature (Tre) and heart rate (HR) data during flight. Environmental conditions on the ground and in the cockpit were also recorded. Cockpit temperatures during the first week sometimes exceeded 40°C dry bulb temperature and were the hottest environmental temperatures to which pilots were exposed throughout the day. Ambient temperatures were somewhat cooler during the second week. Tre rose nearly 0.5°C during flight in CD gear in both weeks, particularly in response to physical activity, but dropped noticeably during rest periods between flights. By comparison, Tre in STD gear rose only about 0.1°C. HR and other physiological parameters supported the increase in thermal strain in CD vs STD garments. It is concluded that wearing CD garments during simulated CD operations resulted in noticeable but tolerable thermal physiological strain. Hotter ambient conditions combined with real CD operations could, however, lead to unacceptable levels of strain and concomitant decrements in performance.

Frim, J., & Morris, A. (1992). ***Evaluation of personal cooling systems in conjunction with explosive ordnance disposal suits.*** (DCIEM 92-31). Defence & Civil Institute of Environmental Medicine.

Abstract This study examined the capabilities of three technologies (a liquid cooled undergarment, a thickly-ribbed vest of hydrophylic nylon, and an air vest) to alleviate thermal strain in personnel working in Explosives Ordnance Disposal (EOD) clothing under environmental conditions of 18°C @ 40% relative humidity (rh), 34°C @ 40% rh, and 34°C @ 80% rh. Simulated EOD tasks consisted of treadmill walking (10 min), unstacking/carrying/stacking weighted boxes (10 min), and a rest period (15 min) with the EOD helmet and jacket removed, repeated for a target duration time of 90 min. Physiological data included rectal temperature, skin temperature, heart rate, sweat production and evaporation, metabolic rate, and subjective evaluations of thermal comfort and perceived exertion. The results indicated that wearing the EOD suit produces significant increases in thermal physiological strain over performing the same tasks in a standard station uniform. However, the liquid-cooled Exotemp® personal cooling system was very effective in reducing that strain during heat exposure. Rectal temperatures, heart rates and fluid losses (dehydration) were reduced back to values comparable to those when not wearing the EOD suit, while skin temperatures were actually lower with the cooling system than with only the station uniform. Subjects indicated reduced perceived exertion levels and improved thermal comfort when wearing the liquid-cooled garment with the EOD suit. In contrast, the ribbed vest and air vest showed no significant benefits with the EOD suit. It is concluded that the increase in thermal physiological strain resulting from wearing the EOD suit during EOD work in hot environments can effectively be minimized by use of the Exotemp® personal cooling system.

Jacobs, I., Prusaczyk, W. K., & Goforth Jr., H. W. (1992). ***Muscle Glycogen, Fiber Type, Aerobic Fitness, and Anaerobic Capacity of West Coast U.S. Navy Sea-Air-Land Personnel (SEALs).*** (NHRC No. 92-10). Naval Health Research Center.

Abstract Thirty-eight U.S. Navy Sea-Air-Land personnel (SEALS) participated in aerobic fitness and maximal anaerobic capacity tests on a cycle ergometer. Lactic acid concentration was measured in blood samples collected during the aerobic fitness test. Thirty-six subjects had biopsies taken from the *vastus lateralis* muscle after recording prior dietary intake and physical activity. The biopsy results showed that SEALs had a mean (± SD) of 55% (± 12) fast twitch muscle fiber type. The muscle samples had a

mean glycogen concentration of 404 (± 124) mmol kg^{-1}. Dietary carbohydrate intake over the two days preceding the biopsy was significantly ($p < 0.01$) correlated with extant muscle glycogen concentration. The results of the biopsy indicate that SEALs have an unremarkable fiber type composition (55% ± 12% fast twitch) and a muscle glycogen concentration (404 ± 128 mmol · kg^{-1}) that may put them at risk of insidious glycogen depletion over successive deployment days. Muscle glycogen concentration was significantly ($p < 0.01$) correlated with prior two-day dietary carbohydrate intake normalized for body weight ($n = 21$; $r = 0.63$). The blood lactate concentration during submaximal exercise suggests that SEALs' aerobic fitness was somewhat lower than expected for elite military personnel, approximately equal to that of male college physical education students. The anaerobic capacity tests indicate that SEALs demonstrate only moderate anaerobic fitness. Overall, the results of this study suggest that SEALs would benefit from: a) increasing carbohydrate intake to enhance premission muscle glycogen concentrations (e.g., through dietary carbohydrate supplementation); and b) engaging in combined aerobic and anaerobic training programs that use established scientific principles governing the implementation of mode specificity, frequency, intensity, and duration of exercise.

Keith, S. P., Jacobs, I., & McLellan, T. (1992). **Adaptations to training at the individual anaerobic threshold.** *Eur. J. Appl. Physiol., 65,* 316-323.

Abstract The individual anaerobic threshold (Th_{an}) is the highest metabolic rate at which blood lactate concentrations can be maintained at a steady-state during prolonged exercise. The purpose of this study was to test the hypothesis that training at the Th_{an} would cause a greater change in indicators of training adaptation than would training "around" the Th_{an}. Three groups of subjects were evaluated before, and again after 4 and 8 weeks of training: a control group, a group which trained continuously for 30 min at the Th_{an} intensity (SS), and a group (NSS) which divided the 30 min of training into 7.5-min blocks at intensities which alternated between being below the Th_{an} [Th_{an} – 30% of the difference between Th_{an} and maximal oxygen consumption ($\dot{V}O_2$ max)] and above the Th_{an} (Th_{an} + 30% of the difference between Th_{an} and $\dot{V}O_2$ max. The $\dot{V}O_2$ max increased significantly from 4.06 to 4.27 l·min^{-1} in SS and from 3.89 to 4.06 l·min^{-1} in NSS. The power output (W) at Th_{an} increased from 70.5 to 79.8% $\dot{V}O_2$ max in SS and from 71.1 to 80.7% $\dot{V}O_2$ max in NSS. The magnitude of change in $\dot{V}O_2$ max, W at Th_{an}, % $\dot{V}O_2$ max, at Th_{an} and in exercise time to exhaustion at the pretraining Th_{an} was similar in both trained groups. Vastus lateralis citrate synthase and 3-hydroxyacyl-CoA-dehydrogenase activities increased to the same extent in both trained groups. While all of these training-induced adaptations were statistically significant ($P<0.05$), there were no significant changes in any of these variables for the control subjects. These results suggest that the relative stimulus for physiological adaptation to training was similar in SS and NSS. These results also demonstrate that, when training intensity is set relative to the Th_{an}, it is the mean intensity during training that determines the extent of adaptation regardless of whether the exercise is performed intermittently or continuously.

Martineau, L., Horan, M. A., Rothwell, N. J., & Little, R. A. (1992). **Salbutamol, a $ß_2$-adrenergic agonist, increases skeletal muscle strength in young men.** *Clin. Sci., 83,* 615-621.

Abstract $ß_2$-adrenoceptor agonists have been shown to increase rapidly lean body mass and reverse muscle wasting in sev-

eral animal models of human illness. However, no published information is available for humans. In the present study, we investigated the effects of a slow-release preparation of salbutamol or a placebo on skeletal muscle functional capacity in 12 healthy men. The strength of different muscle groups was measured on two occasions prior to, and after 14 and 21 d of treatment. No significant changes in muscle strength were observed with placebo during the trial. In contrast, the strength of both quadriceps muscles increased significantly (12 ± 3 %) after 14 d on salbutamol, and remained elevated at 21 d. Whereas the strength of the hamstring muscles of the dominant leg significantly increased after 21 d on salbutamol (22 ± 6%), the strength of the non-dominant hamstring muscles returned to baseline values. There was no significant change in the grip strength of either hand in these subjects during the trial. The maximal static inspiratory mouth pressure significantly increased after 14 d (7 ± 2%) on salbutamol, and increased further after 21 d (15 ± 4%); the expiratory mouth pressure remained constant. No significant changes in body weight, skinfold thickness, lean body mass, or limb circumferences were measured in either group. These data demonstrate that short-term administration of salbutamol increases involuntary muscle strength in man. However, the magnitude and duration of this effect vary between muscle groups. This study implies that the $ß_2$-adrenoceptor agonists may be of therapeutic potential in altering skeletal muscle function in humans.

Martineau, L., & Jacobs, I. (1992). **Substrate availability and temperature regulation during cold water immersion in humans.** In R. Y. Nishi (Ed.), *Proceedings of the DCIEM Diver Thermal Protection Workshop, 31 Jan - 2 Feb 1989*, DCIEM No. 92-10, (pp. 125-130). North York, Ontario: Defence and Civil Institute of Environmental Medicine.

Abstract Increased thermogenesis in humans during cold exposure is caused by shivering. Although there is much evidence that both circulating and intramuscular substrates are used to fuel this enhanced skeletal muscle activity, there are no studies describing the effects of altering substrate availability on human temperature regulation. This abstract reports the results from two studies. The importance of skeletal muscle glycogen as a fuel for shivering thermogenesis in humans during cold water immersion was first clarified. It was then investigated whether a reduced availability of plasma free fatty acids (FFA) would impair cold tolerance.

Study I. Eight lean male subjects, wearing only bathing suits, were immersed to the chest in 18° C water three times over a three-week period. Each immersion continued until 90 min had elapsed or rectal temperature (T_{re}) decreased to 35.5° C. Each immersion followed 2.5 days of a specific dietary and/or exercise regimen designed to elicit low (L), normal (N), or high (H) glycogen concentration in large muscle groups. Biopsies from the vastus lateralis muscle showed that glycogen concentration before the immersion was significantly ($p<0.01$) lower for L than for N or H. The calculated metabolic heat production during the first 30 min of immersion was significantly lower ($p<0.05$) during L as compared to N or H. The rate at which T_{re} decreased was more rapid ($p<0.05$) during L than either N or H, and the time during the immersion at which T_{re} first began to decrease also appeared sooner ($p=0.08$) during L than N or H. The immersion time was significantly shorter ($p<0.05$) during L than either N or H. There were no differences between the thermoregulatory responses of N and H.

Study II. Seven seminude male subjects were immersed in 18° C water after 2 hours of intermittent oral ingestion of either a placebo (PLAC) or nicotinic acid (NIC), a potent antilipolytic agent. Plasma FFA levels immediately before the immersion were eight times lower ($p<0.05$) in NIC than in PLAC. Although FFA levels increased

($p<0.05$) in NIC after the immersion, they remained five times lower ($p<0.05$) than in PLAC throughout the immersion. Muscle glycogen concentrations in the vastus lateralis decreased ($p<0.05$) following cold water immersion in both trials, but the rate of glycogen utilization was similar. The decrease in plasma glucose levels following immersion was greater ($p<0.05$) in NIC than in PLAC. Mean RER immediately before the immersion was greater ($p<0.05$) in NIC than in PLAC. There were no intertrial differences either in the calculated metabolic heat production during immersion or between the thermoregulatory responses of PLAC or NIC.

The results demonstrate clearly that low skeletal muscle glycogen levels may be associated with more rapid body cooling in humans. Higher than normal glycogen levels, however, do not increase cold tolerance. Furthermore, the data indicate that a reduced availability of FFA does not alter human temperature regulation during cold water immersion. Apparently, any reduced heat production transduced from plasma FFA may be replaced by energy from other substrates.

McLellan, T., & Cheung, K. S. Y. (1992). **A comparative evaluation of the individual anaerobic threshold and the critical power.** *Med. Sci. Sports Exerc., 24,* 543-550.

Abstract The individual anaerobic threshold (IAT) is defined as the highest metabolic rate where blood lactate (La) concentrations are maintained at a steady-state during prolonged exercise. The asymptote of the hyperbolic relationship between power output and time to fatigue has been defined as the critical power (CP) which, in theory, represents the highest metabolic rate where a steady-state response can be achieved during prolonged exercise. Since IAT and CP may define the same power output, the purpose of this study was to compare the gas exchange, blood La and acid-base responses during exercise at the metabolic rates defined as IAT and CP. Fourteen males performed a maximal incremental cycle exercise test which was followed by a light active recovery period to determine IAT. Subsequently, subjects exercised to fatigue at five power outputs (calculated to elicit from 90% to 110% $\dot{V}O_2$ max) to determine CP. IAT occurred at a significantly lower power output and $\dot{V}O_2$ (235 ± 44 W and 2.97 ± 0.47 $L \cdot min^{-1}$, respectively) compared with CP (265 ± 39 W and 3.35 0.41 $L \cdot min^{-1}$, respectively). During 30 min of exercise at IAT blood La levels increased during the initial 10 min to 3.9 ± 1.9 $mmol \cdot L^{-1}$ but did not change during the final 15 min. Blood pH decreased to 7.32 ± 0.04 at 5 min and did not change thereafter, while PCO2 fell from 41.5 ± 3.2 mmHg at 5 min to 36.2 ± 3.6 mmHg at 30 min. Only one subject completed 30 min of exercise at CP. For thirteen subjects who completed 15 min, La values increased from 5.0 ± 1.1 $mmol \cdot L^{-1}$ at 5 min to 6.8 ± 1.9 $mmol \cdot L^{-1}$ at 15 min, pH decreased to 7.28 ± 0.03 at 5 min and remained unchanged and PCO2 decreased from 40.8 ± 3.8 mmHg at 5 min to 33.7 ± 2.0 at 15 min. It is concluded that the methods used to determine CP overestimate the metabolic rate associated with a maximal steady-state blood La and acid-base response.

McLellan, T. M., Cheung, S. S., & Meunier, M. R. (1992). **The effect of normocapnic hypoxia and the duration of exposure to hypoxia on supramaximal exercise performance.** *Eur. J. Appl. Physiol., 66,* 409-414.

Abstract Two investigations were designed that, a) evaluated the effect of the respiratory alkalosis that accompanies breathing an hypoxic gas mixture and, b) examined the influence of the duration of breathing the hypoxic gas on the subsequent performance of 45-s of supramaximal dynamic exercise. In experiment 1, twelve males performed a 45-s Wingate Test (WT) on three occasions breathing a normoxic (N, 20.9% O_2), hypoxic (H, 11.3% O_2) or normo-

capnic hypoxic ($H+CO_2$, 11.5% O_2, 2.25% CO_2) gas mixture with a minimum of 48 h between tests. Subjects breathed the humidified gas mixtures from a spirometer for 20 min prior to performing the 45-s WT. For experiment 2, nine males performed a normoxic (N20) and three hypoxic WT trials. The hypoxic conditions consisted of breathing an 11% O_2 balance N2 gas mixture for 10-min (H10), 20-min (H20) or 30-min (H30) prior to the WT. Resting blood oxygen saturation was monitored with an ear oximeter and decreased during the hypoxic trials from 98% to ~85%. Arterialized blood samples for lactate, pH, blood gases and catecholamines (in experiment 1) were taken before and at the end of the period breathing the gas mixture, immediately following the WT and during a 10-min recovery period breathing room air. Open-circuit spirometry was used to calculate the total $\dot{V}O_2$ during WT. For experiment 1, $\dot{V}O_2$ was significantly reduced during the 45-s H (1.22 ± 0.23 L) and H^+CO_2 (1.12 ± 0.18 L) WT trials compared with the normoxic trial (1.78 ± 0.18 L). Peak power output during WT was similar across trials. However, a small (less than 3%) but significant reduction in the mean power output was observed for both H and H^+CO_2 (6.8 ± 0.6 $W \cdot kg^{-1}$) compared with N (7.0 ± 0.6 $W \cdot kg^{-1}$). Prior to performing the WT, blood pH and pCO_2 were similar (7.40 ± 0.02 and 5.3 ± 0.3 kPa, respectively) for the N and H^+CO_2 trials. A respiratory alkalosis accompanied the H condition (7.46± 0.02 for pH and 4.6 ± 0.3 kPa for pCO_2). Blood lactate and plasma catecholamines were similar among the three trials both before and after WT. For experiment 2, $\dot{V}O_2$ also was significantly lower during the 45-s WT for H10 (1.16 ± 0.16 L), H20 (1.17 ± 0.16 L) and H30 (1.18 ± 0.26 L) compared with N20 (1.84 ± 0.41 L). In addition, peak power output was similar across trials but a significant reduction in mean power output was observed for the hypoxic trials (7.1 ± 0.4 $W \cdot kg^{-1}$) compared with N20 (7.4 ± 0.4 $W \cdot kg^{-1}$). These data conflict with our previous findings (McLellan et al. 1990) and suggest that the respiratory alkalosis that accompanies breathing an hypoxic gas mixture does not influence performance of a 45-s WT. Also, the conflicting results cannot be attributed to the length of breathing the hypoxic gas mixture prior to the performance of the WT.

McLellan, T. M., Meunier, P., & Livingstone, S. (1992). **Influence of a new vapour protective clothing layer on physical work tolerance times at 40° C ambient temperature.** *Aviat. Space Environ. Med., 63,* 107-113.

Abstract The purpose of the present study was to examine the influence of a new vapor protective clothing on physical work performance in a hot environment (40°C and 25% relative humidity). Eleven unacclimatized males (28 ± 6 years, 79 ± 8 kg, 1.76 ± 0.06 m) were assigned to exercise at either a light intermittent (L) (N = 6), or heavy continuous (H) (N = 5) metabolic rate. Group L alternated between 15 min of walking on a treadmill at 1.11 ms^{-1} with a 0% grade and 15 min of rest. Group H walked continuously at 1.33 ms^{-1} with a 3% grade. Subjects were tested wearing three clothing configurations: full nuclear, biological and chemical (NBC) protection (TOPP High) with the combat clothing worn under the NBC garment (TH + CC); full NBC protection without combat clothing (TH - CC); the new vapor protective clothing together with the NBC gloves, boots, and respirator (NPC). WTT was the time-period until rectal temperature (Tre) reached 39.3°C, heart rate reached 95% maximum, dizziness or nausea precluded further exercise, or 3 h had elapsed. For group L, WTT was similar for TH + CC (113 ± 12 min) and TH - CC (139 ± 18 min). WTT was significantly increased for NPC where all subjects completed the 3 h in the climatic chamber. The rate of increase for Tre was significantly reduced for NPC (0.3 ± 0. 1°Ch^{-1}) compared with both TH + CC (0.9 ± 0.1°Ch^{-1}) and TH -

CC ($0.8 \pm 0.2°Ch^{-1}$). The evaporative efficiency of the new clothing ensemble ($76 \pm 4\%$) was also significantly increased compared with both TH + CC ($36 \pm 17\%$) and TH - CC ($46 \pm 9\%$). For group H, WTT significantly increased from TH + CC (46 ± 15 min) to TH - CC (60 ± 21 min) and to NPC (85 ± 28 min). The rate of increase in Tre was not different among the three clothing configurations. Evaporative efficiency was significantly different among the three clothing trials ($19 \pm 18\%$, $38 \pm 4\%$ and $57 \pm 7\%$ for TH + CC, TH - CC and NPC, respectively). For both groups, mean skin temperature and heart rates reflected the differences in the evaporative efficiency of the clothing comparisons. The results of this experiment clearly show the benefits of the new vapor protective clothing on physical work performance in a hot environment. Also, the data strongly suggest that, if possible, the combat clothing should not be worn under the present NBC garment.

Savourey, G., Vallerand, A. L., & Bittel, J. H. M. (1992). **General and local cold adaptation after a ski journey in severe Arctic environment**. *Eur. J. Appl. Physiol., 64,* 99-105.

Abstract It is hypothesized that some of the variability in the conclusions of several human cold adaptation studies could be explained if not only were the change in core and shell temperatures taken into account, before and after cold adaptation, but also the absolute temperatures and metabolic rate in both thermally neutral environments and in the cold. Such an approach was used in a group of volunteers before and after a ski journey (3 weeks at –20 to –30°C) across Greenland. Eight subjects were submitted to cold tests (T_{db}= 1°C, r.h. = 40%, wind speed = 0.8 $m \cdot s^{-1}$) for 2 hours. Thermoregulatory changes were also monitored in a neutral environmen$_t$ (T_{db} = 30°C). In the neutral environment, the arctic journey increased metabolic rate (11.2%; $P<0.05$) and mean skin temperature (T_{sk}: 33.5 (SEM 0.2)°C vs 32.9 (SEM 0.2)°C, $P<0.05$]. During the cold test, the arctic journey was associated with a lower final rectal temperature [36.8 (SEM 0.2)°C vs 37.3 (SEM 0.2)°C, $P<0.01$], a lower final T_{sk} [20.7 (SEM 0.4)°C vs 21.2 (SEM 0.3)°C, $P<0.01$] with no change in metabolic heat production. These observations are indicative of an hypothermic insulative isometabolic general cold adaptation, which was associated with a local cold adaptation of the extremities, as shown by warmer foot temperatures [12.3 (SEM 0.9)°C vs 9.8 (SEM 0.9)° C, $P<0.001$].

Tikuisis, P. (1992). **Development of whole-body models for thermoregulation in the cold**. In K. R. Diller & A. Shitzer (Eds.), *Macroscopic and Microscopic Heat and Mass Transfer in Biomedical Engineering.* (pp. 126-137). New York: Elsevier Press.

Abstract Whole-body models of human thermoregulation have been developed over the past three decades. While generally successful when applied to conditions of heat stress, their predictive performance for conditions of cold stress has been limited. This is largely due to the greater individual variability in response to cold and to the much larger gradients in tissue temperature. To obtain agreement with measured values of body temperature and metabolic rate, several parameters governing thermoregulation are introduced to the models, e.g. efferent shivering commands based on peripheral and central temperatures, contribution of muscles to heat production, conduction of heat, and extent of counter-current heat exchange. The characterization of the flow and temperature of blood is regarded especially important since blood flow to the limbs is the principal contributor of heat in the limbs. Most model parameters are rationally derived, yet some are mathematically constructed to obtain a good fit. In an effort to improve model parameterization, several experiments were conducted to measure key responses and properties during cold stress.

These experiments were to 1) characterize the relationship between metabolic response and body fatness, 2) determine the onset of shivering and the contribution to the overall heat production of various muscle during shivering, 3) determine the "in vivo" thermal conductivity of cold limb tissues, and 4) determine the extent of radial counter-current heat exchange in the limbs. The results of these investigations are reviewed and their implementation into whole-body models of thermoregulation is discussed. Prediction based on a revised model with these new findings are compared with previous predictions.

Tikuisis, P. (1992). **Prediction of thermoregulatory response for clothed immersion in cold water.** In R. Y. Nishi (Ed.), *Proceedings of the DCIEM Diver Thermal Protection Workshop, 31 Jan - 2 Feb 1989,* DCIEM No. 92-10, (pp. 165-175). North York, Ontario: Defence and Civil Institute of Environmental Medicine.

Abstract A multi-compartmental thermoregulatory model was applied to data of ten resting clothed males immersed for 3 h in water at 10 and 15 °C. Clothing consisted of a dry suit and either a light or heavy undergarment, representing a total insulation of 0.15 (0.95) or 0.20 m^2 ° C/W (1.28 clo), respectively. Data were grouped according to low (<14%) and high (14 to 24%) body fat individuals. Mean decreases in rectal temperature ranged from 0.79 to 1.38 °C, mean decreases in the mean weighted skin temperature ranged from 6.3 to 10.2 ° C, and mean increases in the metabolic rate ranged from 33.9 to 80.8 W. The model consists of eight segments, each representing a specific region of the body. Each segment is comprised of compartments representing the core, muscle, fat, skin, and clothing. Each compartment is assigned thermophysical values of heat conduction and heat capacitance, and with the exception of clothing, physiological values of blood flow and metabolic heat production. During cold exposure, responses are directed towards increased heat production in the form of shivering and heat conservation in the form of vasoconstriction and counter-current heat exchange. Agreement between the model predictions and the experimental observations was obtained by adjusting the parameters governing these responses. These adjusted parameters were 1) the delayed onset of limb shivering with an exponential half-time of 30 min, 2) the fractional value of 0.5 for the heat exchange between the core compartments of the limbs and the blood flowing through these compartments, 3) the fractional contribution of trunk shivering to overall shivering, which ranged from 0.77 to 0.95, and 4) the delayed onset of vasoconstriction with half-times, which ranged from 3 to 25 min. Steady state was predicted to occur within 4 h and an analysis of heat balance indicated that the limbs were responsible for most of the body's heat loss while acquiring most of their own heat from the trunk through conduction with the central blood.

Vallerand, A. L., & Jacobs, I. (1992). **Energy metabolism during cold exposure.** *Intl. J. Sports Med,, 13*(Suppl. 1), S191-S193.

Abstract Recent advances on the influence of cold exposure on energy metabolism in animals and humans are summarized. Although the cold-induced increases in carbohydrate metabolism have been the focus of numerous studies, it was only recently that evidence from animal studies suggested that cold exposure exerts an insulin-like effect on peripheral tissue glucose uptake, which appears to proceed primarily via insulin-independent pathways. Interestingly, this phenomenon was observed in insulin-sensitive tissues of warm- as well as cold-adapted rats. Whereas previous human studies have described the cold-induced changes in basal levels of hormones and metabolic substrates, recent work from our laboratory has demonstrated that exposure to cold at rest shifts

substrate utilization from being mainly lipid-dependent at thermal neutrality to carbohydrates, representing the main fuel for shivering thermogenesis. Further investigation has revealed that the marked increase in carbohydrate oxidation in cold-exposed humans is derived from a greater utilization of both circulating glucose and intramuscular glycogen. With respect to lipid metabolism, recent studies have shown that the cold-induced increase in lipid oxidation in man is fueled primarily by the fatty acids released from white adipose tissue triglycerides (TG) and possibly intramuscular TG, not plasma TG. One practical application of this work on energy metabolism in the cold resides in the pharmacological/nutritional approach to improve cold tolerance, where pharmacological agents that alter energy metabolism and substrate utilization could be used to enhance cold thermogenesis and produce warmer body temperatures.

Vallerand, A. L., & Jacobs, I. (1992). **Review of pharmacological approaches to improve cold tolerance.** In R. Y. Nishi (Ed.), *Proceedings of the DCIEM Diver Thermal Protection Workshop, 31 Jan - 2 Feb 1989,* DCIEM No. 92-10, (pp. 119-123). North York, Ontario: Defence and Civil Institute of Environmental Medicine.

Abstract A pharmacological approach to the problem of enhancing cold tolerance in humans is currently the subject of greater attention. Two approaches are possible. First, drugs that minimize heat loss could delay hypothermia but would also be associated with lower mean skin temperature, the loss of manual dexterity and a greater danger of frostbite. Secondly, agents that increase heat production could increase resistance to cold by producing warmer body temperatures. By using hormones, theophylline, caffeine, amphetamines etc. for various periods of time, heat production and cold tolerance have been improved in animal studies. However, a generalization to humans should be made with caution particularly in view of the small animal's capacity for brown fat nonshivering thermogenesis. In humans exposed to comfortable ambient temperatures, recent studies have firmly established that Beta-adrenergic drugs such as ephedrine, and methylxanthines such as caffeine increase heat production. Similarly, a mixture of ephedrine/caffeine is presently considered a very promising thermogenic drug in man because it has shown safe thermogenic properties in both short- and long-term studies. Since its thermal benefit to cold-exposed humans is unknown, the influence of ephedrine (1 mg/kg)/caffeine (2.5mg/kg) on cold tolerance was investigated in 9 healthy young male subjects during two semi-nude exposures to cold air (3 h at 10°C). The drug ingestion reduced the total drop in core, mean skin and mean body temperatures ($p<0.01$), thus producing significantly warmer final core, mean skin and mean body temperatures in comparison to the placebo ingestion. The drug ingestion increased the total 3 h energy expenditure by 18.6% in comparison to that of the placebo ingestion in the cold ($p<0.01$). Using the non-protein respiratory exchange ratio to calculate the rates of substrate oxidation, it was found that the drug ingestion increased carbohydrate oxidation by 41.7% above that of the placebo ($p<0.05$), but did not alter lipid or protein metabolism. The results demonstrate that the ingestion of an ephedrine/caffeine mixture improves cold tolerance in man by significantly increasing body temperatures in the cold. These improvements were caused by a greater energy expenditure, which appears to be dependent on an enhanced carbohydrate utilization.

Vallerand, A. L., & Jacobs, I. (1992). **Lipid metabolism in cold exposed humans.** In R. Y. Nishi (Ed.), *Proceedings of the DCIEM Diver Thermal Protection Workshop, 31 Jan - 2 Feb 1989,* DCIEM No. 92-10, (pp. 139-142). North York, Ontario: Defence and Civil Institute of Environmental Medicine.

Abstract The goal of this study was to determine the changes in lipid utilization associated with cold exposure in humans, and whether plasma triglyceride (TG) and lipolysis play an important role in lipid metabolism during cold exposure. This was achieved by: calculating the rates of substrate oxidation from indirect calorimetry, by performing an intravenous fat tolerance test (IVFTT; an index of plasma TG utilization) and by measuring changes in plasma glycerol levels (an index of lipolysis). Since fat clearance is increased 24 h after exercise, a second cold exposure combined with an IVFTT were also performed 24 h after the first cold exposure, to evaluate the possibility of a delayed increase in fat tolerance. Six healthy males were therefore subjected to an IVFTT (1 ml/kg 10% Intralipid) on 3 occasions (fasting semi-nude) while resting for 160 min: 1) at thermal neutrality (29°C), 2) in the cold (10°C, 1 m/s wind) and 3) in the cold 24 h after the first cold test. One week separated the warm test from the two cold tests. Cold exposure reduced mean body temperature by 3.2 ± 0.1° C and increased energy expenditure 2.6 times in comparison to warm values ($p<0.01$). It also increased fat oxidation by 71% ($p<0.01$) and plasma glycerol levels ($p<0.05$), but did not alter the removal rate of the infused plasma TG. Although the second cold test entailed essentially the same changes in body temperatures and heat production as the first one, the second cold test was accompanied by a further increase in fat utilization (142% above warm values, $p<0.01$; or 56% of the energy expenditure), a further increase in plasma glycerol levels ($p<0.05$) and an unchanged fat tolerance. The results of the present study demonstrate that cold exposure in humans significantly increases the oxidation of lipid, and that plasma TG do not appear to be an important energy substrate in the cold, even when lipid metabolism is further increased by the second cold test. It is suggested that white adipose tissue and possibly intramuscular TG, not plasma TG, are the preferred sources of fatty acids for oxidation in cold-exposed humans.

Vallerand, A. L., Savourey, G., & Bittel, J. H. M. (1992). **Determination of heat debt in the cold: Partitional calorimetry vs. conventional methods.** *J. Appl. Physiol.*, 72(4), 1380-1385.

Abstract Measurements of core temperature (T_c) at different sites produce on some occasions different cooling curves in cold-exposed humans, suggesting that the corresponding thermometric heat debts (HD) could be equally different, when calculated by conventional methods [via either the change in T_c or mean body temperature (T_b)]. The present study also compared these thermometric HD values to the calorimetric HD (S) obtained by partitional calorimetry. Nine subjects who showed similar initial but different final T_c [rectal (T_{re}) and auditory canal temperatures (T_{ac})] during nude cold exposure (2h at 1°C at rest) were used. T_c-derived HD corresponded to a heat gain of 12±21 kJ and a HD of 78±20 kJ using T_{re} and T_{ac} respectively, whereas the T_c-derived HD varied from 266±35 to as much as 1479±71 kJ using various well-known T_b weighing coefficients. In contrast, S corresponded to 504±79 kJ, a level that could only have been obtained if the thermoneutral/cold T_b weighing coefficients had been .818/.818 for T_{re} and .865/.865 for T_{ac}. The results demonstrate that HD calculated by conventional methods can markedly overestimate or underestimate heat debt. These differences could not be explained by the site chosen to represent T_c, since about the same effect was observed using either T_{re} or T_{ac}. It is concluded that thermometric HD in the cold is not, at least under the present conditions, as accurate and reliable as the S of partitional calorimetry.

Vallerand, A. L., Savourey, G., Hanniquet, A.-M., & Bittel, J. H. M. (1992). **How should heat storage be determined in humans: by thermometry or calorimetry?** *Eur. J. Appl. Physiol., 65,* 286-294.

Abstract The aim of this study was to determine whether in humans there are differences in the heat storage calculated by partitional calorimetry (S, the balance of heat gains and heat losses) compared to the heat storage obtained by conventional methods (thermometry) via either core temperature or mean body temperatures (T_b= $0.8T_c$+0.2 T_{sk}, where T_c is core temperature and T_{sk} is mean skin temperature) when two different sites are used as an index of T_c [rectal (T_{re}) and auditory canal temperatures (T_{ac})]. Since women respond to the heat differently than men, both sexes were studied. After a stabilization period at thermal neutrality, six men and seven women were exposed to a globe temperature of 50°C, relative humidity of 17% and wind speed of 0.8-1.0 $m.s^{-1}$ for 90 min semi-nude at rest, where T_{re}, T_{ac}, T_{sk}, metabolic rate, dry and evaporative (E) heat losses, S, heat storage by T_c (ST_c) and heat storage by T_b (ST_b) were assessed every min. In the men, S was equal to 350.8(SEM49.6) kJ whereas ST_c amounted to only 114.6 (SEM 16.2) and 196.7 (SEM 32.3) kJ for T_{re} and T_{ac}, respectively ($P<0.05$). Final $ST_{b(re)}$ underestimated S by 49% [177.7(SEM23.0) kJ; $P<0.05$] whereas $ST_{b(ac)}$ was not significantly different than S [255.7(SEM37.9) kJ]. In the women, S corresponded to a total of 294.3 (SEM 23.2) kJ, a value that was very similar to the $ST_{b(ac)}$ [262.6 (SEM 31.0) kJ], whereas $ST_{b(re)}$ underpredicted S by 35% [190.4 (SEM 26.3) kJ; $P<0.05$]. As in men, ST_c was much lower than S [116.6(SEM19.9) and 190.3(SEM24.2) kJ for T_{re} and T_{ac}, respectively; $P<0.05$]. Using seven other well-known T_b weighting coefficients, ST_b could under- and overestimate S by up to 55% and 11%, respectively. In all subjects, a large portion of the variance (68% and 75%) in the difference between S and ST_b, could be explained primarily by the ΔT_{ac}. The results demonstrate that although some estimates of thermometric heat storage match the calorimetric S, other predictions underestimate it by up to 67% during passive heating. It is suggested that these differences can be explained in part by the site chosen to represent T_c, the use of either T_c or T_b in the heat storage calculation, and the thermoneutral/hot weighting coefficient(s) chosen to determine T_b. Until more accurate measurements of body temperatures at different depths (core, shell and intermediate) are possible, the use of T_b and T_b-derived heat storage is difficult to justify.

Vallerand, A. L., Schmegner, I. F., & Jacobs, I. (1992). ***Influence of the Cold Buster Sports Bar on Heat Dept, Mobilization and Oxidation of Energy Substrates.*** (DCIEM 92-60). Defence and Civil Institute of Environmental Medicine.

Abstract In a recent study, we have shown that the commercially available Cold Buster' Sports bar, purported to improve cold resistance, did not do so in our subjects exposed to a relatively severe cold test. (Vallerand, Tikuisis, Ducharme & Jacobs, In Review). One possible explanation for our conflicting results is that our metabolic rate (M) was too high for the possibly small thermogenic effect of the bar to be measurable. The goal of this study was therefore to re-evaluate, under milder conditions, the influence of the Cold Buster™ on heat balance (heat debt = heat production - heat losses) and body temperatures. Eight semi-nude fasted subjects were exposed to the cold (3h at rest, 10°C, <0.4 m.s-1 wind) on two occasions following the ingestion of either a placebo (100 ml water) or a Cold Buster' (all feedings at min 0 and 90). As a result of the cold, M, dry heat losses and heat debt (S) increased whereas mean skin temperature decreased ($P<0.05$). Rectal temperature remained unchanged due to the mild cold. In all of the above parameters, there were no

differences between treatments. Ingestion of the Cold Buster™ significantly increased carbohydrate oxidation at min 150 compared to the placebo ($P<0.05$). However, this was without impact on M, since it occurred entirely at the expense of fat oxidation (n.s.). Interestingly, the Cold Buster™ increased plasma glucose levels after 2h into the cold ($P<0.05$), a phenomenon which appears to have triggered a large increase in insulinemia ($P<0.05$) This secretion of insulin seems to have blunted lipid mobilization since it significantly reduced plasma free fatty acids levels ($P<0.05$). The results confirm previous data where the ingestion of the Cold Buster™ Sports bar did not alter heat production, heat losses, heat debt or even body temperatures, and extend these observations to a mild cold stress. Although the Cold Buster™ enhanced CHO mobilization and oxidation, this phenomenon occurred entirely at the expense of mobilization and oxidation of lipids. Taken together, these studies do not provide any evidence to support a recommendation for the use of the Cold Buster™ Sports bar.

Vallerand, A. L., Schmegner, I. F., & Michas, R. D. (1992). **Heat strain produced by 3 aircrew CD ensembles under hot conditions: Improvement with an air-cooling vest.** In J. P. McBriarthy & N. W. Henry (Ed.), *Performance of Protective Clothing.*, 4th Volume, ASTM STP 1133, (pp. 583-596). Philadelphia PA,: American Society for Testing and Materials.

Abstract The heat strain produced by three different Canadian Forces chemical defence (CD) individual protection ensembles (IPE) was studied under simulated hot cockpit conditions with an air-cooling vest (AC) and with no cooling (NC). Seven healthy males were randomly subjected to six heat stress tests (37°C, 50% r.h., target of 150 min) using the helicopter IPE with AC-4 mask (H4), the helicopter IPE with AR-5 hood/respirator (H5), and the CF-18 fighter IPE (F) with AR-5 respirator and anti-G suit. Whatever the IPE, AC increased heat exposure time and total heat losses, and decreased the change in core (ΔTre/h) and whole body mean skin temperatures ($\Delta T_{sk(WB)}/h$) ($P<0.05$). Differences with IPEs appeared restricted to the F-NC condition. F-NC produced a lower heat exposure time (vs H4-NC and H5-NC) and sweat evaporation rate (vs H4-NC), and a greater $\Delta T_{sk(WB)}/h$ (vs H4-NC and H5-NC) and T_{re} at min 80 (vs H5-NC) ($P<0.05$). The results demonstrate that air cooling greatly enhances heat tolerance of subjects wearing any of the 3 CD IPEs tested. They also indicate that without cooling, both helicopter IPEs produce slightly better tolerance to heat than the fighter IPE, possibly an influence of the anti-G suit on evaporative cooling.

1993

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1993). *Effects of endurance training on heat-exercise tolerance in men wearing NBC protective clothing.* (DCIEM 93-46). Defence and Civil Institute of Environmental Medicine.

Abstract Sixteen unacclimatized males (27 ± 1 yr, 1.76 ± 0.01 m, 82 ± 3 kg) were assigned to either an 8-week treatment of endurance training (n = 7) or control (n = 9). The training program consisted of four 45-min running sessions per week at 80% of maximal aerobic power $\dot{V}O_2$ max, performed at < 25°C. Subjects were tested before and after treatment wearing either standard military combat clothing (4.4 kg, 1.4 clo) or nuclear, biological and/or chemical (NBC) protective clothing (8.2 kg, 2.5 clo). Test sessions involved treadmill walking at 4.8 $km \bullet h^{-1}$ and 2% grade in a climatic chamber maintained at 40 ± 0.5 °C and 30 ± 1% rh. The heat-exercise tolerance time (HETT) was defined as the time to the first of: (1) a rectal

temperature (T_{re}) of 39.3°C, (2) a heart rate (HR) ≥ 95% of the subject's observed maximum for 3 min, (3) unwillingness of the subject to continue, or (4) elapse of 2 h. Endurance training increased $\dot{V}O_2$ max (39.9 ± 1.7 vs. 46.3 ± 2.3 $ml \bullet kg^{-1} \bullet \min^{-1}$) and plasma volume (+8 ± 2%), but HETT was unchanged in either clothing ensemble. When wearing standard combat clothing, training slowed the rate of increase in HR and decreased mean subjective rating of perceived exertion, with a trend to decreased mean skin temperature ($\overline{T}_{sk}$). When wearing NBC protective clothing, in contrast, the only significant change was a higher post-training $\overline{T}_{sk}$. A training-induced increase of sweat secretion in NBC protective clothing (1.16 ± 0.20 vs. 1.38 ± 0.19 $kg \bullet h^{-1}$) and a parallel but nonsignificant trend in standard combat clothing (0.76 ± 0.06 vs. 0.83 ± 0.07 $kg \bullet h^{-1}$) were not accompanied by any statistically significant increase in sweat evaporation. Evaporative efficiency thus tended to decrease (25.3 ± 3.5 vs. 21.0 ± 2.6% in NBC protective clothing; $p < 0.05$ and 76.8 ± 2.3 vs. 74.2 ± 2.3% in standard combat clothing; NS). The results suggest that endurance training in a relatively cool environment has little effect on the physiological and psychological stresses imposed by wearing NBC protective clothing in hot environments, because added sweat secretion decreases blood volume and increases discomfort without augmenting body cooling.

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1993). ***Effects of heat acclimation on heat-exercise tolerance in untrained and endurance-trained men wearing NBC protective clothing.*** (DCIEM 93-47). Defence and Civil Institute of Environmental Medicine.

Abstract Responses were compared between nine untrained (UT) men and six men who had participated in 8 weeks of endurance training (ET). Both groups underwent 6 days of heat acclimation in a climatic chamber that was maintained at 40 ± 0.5°C and 30 ± 1% rh. Subjects were tested before and after acclimation wearing either standard military combat clothing or nuclear, biological and/or chemical (NBC) protective clothing. Test sessions involved treadmill walking at 4.8 $km \bullet h^{-1}$ and 2% grade for a maximum of 120 min. In UT subjects, heat acclimation increased plasma volume (+8 ± 2%), but $\dot{V}O_2$ max and heat-exercise tolerance time were unchanged. When wearing standard combat clothing, acclimation decreased average values of heart rate, rectal temperature (T_{re}), mean skin temperature ($\overline{T}_{sk}$), thermal discomfort, and metabolic heat production. When wearing NBC protective clothing, the only significant change was in T_{re}. Acclimation induced an increase of sweat secretion but no statistically significant increase of sweat evaporation in NBC protective clothing. In ET subjects, acclimation reduced thermal discomfort when wearing standard combat clothing, and T_{re} and $\overline{T}_{sk}$ when wearing NBC protective clothing. The results suggest that heat acclimation did little to improve exercise tolerance when wearing NBC protective clothing in hot environments, although it reduced thermoregulatory strain by lowering mean body temperature, irrespective of training status. Further, acclimation added little to the benefit resulting from participation in 8 weeks of endurance training other than reducing psychological strain when wearing standard combat clothing in hot environments.

Bell, D. G. (1993). **The Influence of Air Temperature on the EMG/Force Relationship of the Quadriceps.** *Eur. J. Appl. Physiol., 67,* 256-260.

Abstract Surface electromyography (EMG) in the past has been used to estimate the intensity of muscle contraction. These estimates were derived from the EMG/Force

relationship measured at room temperature. How the surface EMG signal is influenced by varying air temperature as it relates to the EMG/Force relationship has yet to be investigated. Thus, this study evaluated the influence of different air temperatures (10°, 23° and 40°C) on surface EMG during contractions of the quadriceps muscle. Ten subjects (mean age of 29±7y and weight of 78.3±7.8kg) performed a criterion task of 5 contractions ranging from 10 to 100% of a maximal voluntary contraction (MVC) 5 times over a 1.5 hour period in all conditions. The EMG signals generated from the rectus femoris, and the forces associated with the contractions, were captured on FM tape and subsequently digitized at a sampling rate of 2000 Hz. The relationship between EMG and force was different under the different conditions; EMG was reduced at a given force as temperature increased, and the EMG increased over time in the 10°C environment. The differences that occurred at the various temperatures were believed to be related to fluid distribution in the muscle and muscle conduction velocity. The data imply that the EMG/Force relationship measured using surface electrodes is influenced by ambient temperature.

Ducharme, M. B., & Frim, J. (1993). ***Insulative properties of two thermo-metal neoprenes.*** (DCIEM 93-53). Defence and Civil Institute of Environmental Medicine.

Abstract The objective of the present study was to compare the thermal resistance of two thermometal neoprenes (titanium and stainless steel coated) to the current Canadian Forces Arctic diving suit neoprene (CF-N) in dry and wet environments. The tests in the dry environment were conducted using a Rapid-k thermal conductivity instrument, and in the wet environment using a custom-made apparatus. The dry tests were conducted at 1 atmosphere in the laboratory, and the wet tests were done in a hyperbaric water chamber maintained at 5°C and at depths of 0, 10, 25, 50, and 100 m. Pre- and post-dive tests were performed on the same samples to investigate the effects of two dives on the thermal resistance of the neoprenes.
It was found that the thermal insulation of the two thermo-metal neoprenes tested was significantly higher than that of the CF-N in both the dry and the wet environments. The best thermo-metal neoprene, the stainless steel coated neoprene, averaged an improvement of 53% in the dry and 60% in the wet environment (ranging from 70% at 0 m to 34% at 100 m). The insulative properties of the thermo-metal neoprenes were affected, however, by the dives, decreasing by about 12% after two dives.
It was concluded that the stainless steel thermo-metal neoprene could be a potential alternative to the current CF Arctic diving suit neoprene but further testing is needed on the long term effects of dives and aging on the insulative properties of the material.

Frim, J., & Ducharme, M. B. (1993). **Heat flux transducer measurement error - a simplified view.** *J. Appl. Physiol.*, *74*(4), 2040-2044.

Abstract Heat flux transducers (HFTs) provide a simple and direct measurement of body heat exchange. Regrettably, HFTs perturb the heat flux at the measurement site, resulting in under estimations of the true heat flux. Equations to correct the discrepancy are available, but most require high precision temperature measurements to be made above and/or below the transducer, and/or deep within the body tissues. Since this is not always feasible, the equations are of limited practical benefit. A theoretical basis for the magnitude of the correction factor in relation to the thermal resistances of the materials both above and below the HFT has been developed and has been verified experimentally. The theory is presented in a graph which can be used to derive the HFT correction factor directly, or as a guide to know that heat flux was measured within a certain accuracy. This may obviate the use of

complicated procedures and equations to perhaps needlessly apply a small correction factor to HFT data.

Jacobs, I. (1993). **Fuelling shivering in humans during cold water immersion.** In AGARD (Ed.), *AGARD Conference Proceedings on the Support of Air Operations under Extreme Hot and Cold Weather Conditions.*, AGARD-CP-540, (pp. 6-1 - 6-3). Neuilly sur Seine, France: AGARD.

Abstract Military cold survival research has traditionally concentrated on ways of conserving body heat. In contrast, this paper will describe our recent investigations of metabolic heat production during cold exposure. In humans increased heat production in the cold is achieved by increased shivering, i.e. involuntary intermittent skeletal muscle contractions, which must be fuelled. Our research has focused on the thermoregulatory effects of manipulating the availability of specific fuel substrates to the shivering musculature. Using procedures such as muscle biopsies to quantify intramuscular substrate utilization, venous blood sampling to quantify circulating substrates, and continuous monitoring of metabolic rates and rectal temperatures during cold exposure, we have demonstrated the importance of skeletal muscle carbohydrates stores for the ability to maintain heat production and delay the onset of hypothermia during cold water immersions. Acute reductions in muscle carbohydrate stores were associated with significant reductions in heat production by the body during shivering, and a more rapid decrease in rectal temperature. In contrast, another series of studies induced acute reductions in circulating fat stores, but there was no effect on body temperature regulation. The availability of sufficient carbohydrate stores to the shivering musculature seems to be critical for the body's ability to delay hypothermia during acute cold stress.

Jacobs, I. (1993). **Technical Evaluation Report.** In AGARD (Ed.), *AGARD Conference Proceedings on the Support of Air Operations under Extreme Hot and Cold Weather Conditions.*, AGARD-CP-540, (pp. T1-T5). Neuilly sur Seine, France: AGARD.

Abstract

Jacobs, I. (1993). **Adaptations to strength training.** In D. A. D. Macleod, R. J. Maughan, C. Williams, C. R. Madeley, J. C. M. Sharp, & R. W. Nutton (Eds.), *Intermittent High Intensity Exercise: Preparation, stresses and damage limitation.* (pp. 27-32). London: E & FN Spon.

Abstract The qualitative and quantitative aspects of adaptations to aerobic/endurance training have been, and continue to be, the focus of much research. The effect of intensity, duration and frequency of the endurance training stimulus, as well as genetic predisposition for specific physiologic adaptations, on the extent of adaptations is well elucidated. Such is not the case for adaptations to strength training. The reader is referred elsewhere for an excellent general review of what is known about strength training methodologies, and applications (Fleck and Kraemer, 1987).
This article will focus on more recent findings concerning some selected skeletal muscle cell responses to acute stimuli in the form of a strength training session, as well as the morphological and neuromuscular adaptations to specific types of strength training sessions. In addition, a brief review of recent literature documenting the effects of combining strength and endurance training will also be presented.

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Jacobs, I., Hermiston, A. J., & Symons, J. D. (1993). **Effects of prior exercise or ammonium chloride ingestion on muscular strength and endurance.** *Med. Sci. Sports Exercise, 25,* 809-814.

Abstract Previous studies have linked muscular fatigue with a decrease in blood pH. The purpose of this investigation was to determine if the means of altering pH affected the extent of muscular fatigue. Thus the effects of drug-induced acidosis and exercise-induced acidosis were compared in order to test the hypothesis that exercise-induced acidosis would impair subsequent muscular performance to a greater extent than would chemically-induced acidosis. In 8 male subjects acidosis was induced by ingestion of 0.3 $g \bullet kg^{-1}$ ammonium chloride (AC) for one trial, by upper body exercise (UBE) for another trial, while a third trial occurred after placebo (PL) treatment. After treatment the subjects completed a performance test (PT) which was 50 maximal, bilateral isokinetic knee extensions. Whole blood was sampled and analyzed for pH before (pH_{pre}) and after (pH_{post}) the PT. pH_{pre} was 7.41, 7.26, and 7.26 for PL, UBE, and AC, respectively; both AC and UBE decreased pH similarly compared to PL. The values for peak torque and total work performed during the PT were similar for PL and AC, and were significantly greater than for UBE. Six of the eight subjects also performed a fourth trial after combined AC and UBE treatments which caused a pH_{pre} of 7.08, but there was no greater impairment on peak torque or total work than that caused by UBE alone. Therefore, a decrease in pH *per se* did not attenuate PT performance. The results dissociate the extent of the impairment from the magnitude of the disruption in blood pH.

Jones, P. J. H., Jacobs, I., Morris, A., & Ducharme, M. B. (1993). **Adequacy of food rations in soldiers during an Arctic exercise measured by doubly labeled water.** *J. Appl. Physiol., 75,* 1790-1797.

Abstract To investigate adequacy of food rations to supply energy needs in cold temperature environments, caloric expenditure and intake, and body composition changes were measured in a group of twenty infantry men during a 10-day field exercise in the Canadian Arctic. The study was carried out in March, 1992, near Iqaluit, Baffin Island. The subjects were from Alpha Company of the First Royal Canadian Regiment based in London, Ontario. Energy expenditure was measured by doubly labeled water; energy intake was measured b y complete food intake records; body composition changes were determined using isotope dilution and bioelectrical impedance techniques. The average daily energy expenditure was calculated to be 4317 $\pm$ 927 kcal and the self reported caloric intakes were reported to be only 2633 $\pm$ 499 kcal daily. The ration packs contained approximately 4350 kcal per day. The body composition changes were minimal, however, suggesting that the food intake was significantly under-reported. The energy needs of most of the subjects were being met by rations and available food supplements. The field trial involved only low to moderate levels of physical exertion; if more intense physical activity were to be carried out for a more prolonged duration than the present Arctic ration pack would be insufficient to avoid a cumulative caloric deficit.

McLellan, T. M. (1993). **Work performance at 40°C with Canadian Forces biological and chemical protective clothing.** *Aviat. Space Environ. Med., 64,* 1094-1100.

Abstract This study examined the effects of a hot environmental temperature (40°C and 50% relative humidity) and metabolic rate on soldiers' tolerance time (TT) while wearing various levels of the Canadian Forces biological and chemical (BC) defence protective clothing. The subjects, 19 unacclimatized males, were assigned to exercise at either a light intermittent (LI)

(N = 4), light continuous (LC) (N = 5), moderate continuous (MC) (N = 5) or heavy continuous (HC) (N = 5) metabolic rate. For groups LI and LC, exercise involved walking on a treadmill at 4.0 km/h with a 0% grade and lifting 10 kg boxes. LI alternated between 15 min of exercise and 15 min of rest. Group MC walked at 4.8 km/h with a 3% grade and lifted 15 kg boxes. Group HC walked at 4.8 km/h with a 7.5% grade and lifted 20 kg boxes. Subjects were tested wearing three levels of clothing protection: combat clothing (L), combat clothing and a semi-permeable BC overgarment (M); combat clothing and BC overgarment, gloves, boots and respirator (H). TT was the time until rectal temperature reached 39.3°C, heart rate reached 95% maximum, dizziness or nausea precluded further exercise, or 5 h had elapsed. For group LI, TT was similar for L(137 ± 15 min) and M (117± 9 min) clothing. TT was significantly reduced for H (67 ± 6 min) clothing. For group LC, TT was greater for L (91 ± 11 min) compared with either M (68 ± 7 min) or H (55 ± 2 min) clothing. For group MC, TT was greater for L (51 ± 5 min) compared with H (35 ± 2 min) but TT for both of these levels of protective clothing was not different from M (44 ± 2 min) clothing. Finally, for group HC, TT was significantly reduced from L (43 ± 6 min) to M (32 ± 6 min) to H (25 ± 3 min) clothing. The decreasing curvilinear relationship between TT and the average metabolic rate was described by a hyperbolic function for each level of BC protection. The vertical asymptote of these functions defined the metabolic rate associated with infinite TT. For each level of BC protection, a resting metabolic rate was above the value associated with infinite TT. These findings implied that even under resting conditions body heat storage and the increase in core temperature would continue. Although intermittent rest periods alone may not reduce the risk of heat casualties, tolerance time will be increased.

McLellan, T. M., & Jacobs, I. (1993). **Reliability, reproducibility and validity of the individual anaerobic threshold.** *Eur. J. Appl. Physiol., 67,* 125-131.

Abstract The individual anaerobic threshold (IAT) is defined as the highest metabolic rate at which blood lactate (LA) concentrations are maintained at a steady-state during prolonged exercise. The validity of this definition, however, has not been substantiated. Eleven males ($\dot{V}O_2$ max = 57.8 mL/ kg/ min) did two maximal incremental cycle exercise tests (30 W and 4 min per step). Blood was sampled repeatedly during exercise and for 9 min during the subsequent light active-recovery period. The subjects then exercised at the power output equivalent of IAT for 45 min, until they could no longer continue or until rectal temperature reached 39 degrees C. Subjects performed two additional exercise tests. The intensity of these tests depended upon the LA and acid-base responses during the last 15-min of at least 30-min of exercise at IAT. If a steady-state was achieved (LA, pH and PCO2 changed less than 0.5 mmol/ L, 0.005 pH units and 2.0 mmHg, respectively) or decreasing La and increasing pH values were observed, then the second test was performed at IAT + 5% $\dot{V}O_2$ max and the third session at either IAT + 2.5% or + 7.5% $\dot{V}O_2$ max. Conversely, if a steady-state was not achieved during exercise at the calculated IAT, the intensity of the second test was set at IAT - 5% $\dot{V}O_2$ max. Depending on the LA and acid-base responses during this test, the final session was performed at either IAT - 2.5% or - 7.5% $\dot{V}O_2$ max. Test-retest reliability for the determination of IAT was high (r = 0.98, SEest was 8 W or 2% $\dot{V}O_2$ max) and the method was reproducible (240.3 W for test 1 and 236.6 W for test 2). However, only four subjects completed at least 30 min of exercise at IAT with steady-state La and acid-base responses. None of these subjects showed steady-state responses at +5% $\dot{V}O_2$ max

above IAT and only one met the criteria at +2.5% $\dot{V}O_2$ max above IAT. Therefore, for these individuals the incremental exercise test underestimated the "true" IAT by less than 5% $\dot{V}O_2$ max. For the other seven subjects, four met the steady-state criteria at both -5% and -2.5% $\dot{V}O_2$ max below the calculated IAT suggesting the "true" IAT was overestimated by less than 2.5% $\dot{V}O_2$ max. For two of the remaining subjects, the incremental exercise test overestimated the "true" IAT by at least 7.5% $\dot{V}O_2$ max. Therefore, the maximal incremental exercise test followed by a light active recovery period will produce a reliable and reproducible estimate of IAT which is valid for the majority of subjects. However, since the method overestimates the "true" IAT for some individuals, the procedure cannot be assumed (without verification) to be valid for all subjects.

McLellan, T. M., Jacobs, I., & Bain, J. B. (1993). **Influence of temperature and metabolic rate on work performance with Canadian Forces NBC clothing.** *Aviat. Space Environ. Med., 64,* 587-594.

Abstract This study examined the effects of environmental temperature and metabolic rate on soldiers' work tolerance time (WTT) while wearing various levels of nuclear, biological and chemical (NBC) defence protective clothing. Twenty-three unacclimatized males (23 ± 3 y, 76 ± 8 kg, 1.77 ± 0.08 m) were assigned to exercise at either a light (walking 1.11 $m \bullet s^{-1}$ 0% grade, alternating with lifting 10 kg) or heavy metabolic rate (walking 1.33 $m \bullet s^{-1}$ 7.5% grade, alternating with lifting 20 kg) in an environmental chamber at either 18°C, 50% R.H. (cool) or 30°C, 50% R.H. (warm). Subjects were tested wearing three levels of clothing protection: combat clothing (L); combats and a semi permeable NBC overgarment (M); combats and NBC overgarment, gloves, boots and respirator (H). WTT was the time until rectal temperature (T_{re}) reached 39.3°C, heart rate reached 95% maximum, dizziness or nausea precluded further exercise, or 5 h had elapsed. During the light and cool trials (N=5), wearing M or H did not impair WTT (277 ± 47 min). For the light and warm experiments (N=6), WTT was significantly impaired with H (82.7 ± 10.6 min). With the heavy and cool condition (N=6), WTT was reduced with M (240.5 ± 73.8 min) and H (56.7 ± 17.9 min). Finally, during the heavy and warm trials (N=6), WTT was progressively impaired for L (172.5 ± 52.8 min), M (65.8 ± 18.2 min) and H (34.0 ± 9.7 min) levels of protection. These data quantify the impairment in physical work performance associated with wearing the Canadian Forces NBC protective clothing as the metabolic rate and/or the environmental temperature is increased.

McLellan, T. M., Jacobs, I., & Bain, J. B. (1993). **Continuous versus intermittent work with Canadian Forces NBC clothing.** *Aviat. Space Environ. Med., 64,* 595-598.

Abstract This study examined the benefits of work and rest schedules on soldiers' work tolerance time (WTT) while wearing various levels of nuclear, biological and chemical (NBC) defence protective clothing in a warm environment (30°C and 50% R.H.). Eight unacclimatized males were assigned to exercise at either a light (walking 1.11 $m \bullet s^{-1}$ 0% grade, alternating with lifting 10 kg) or heavy metabolic rate (walking 1.33 $m \bullet s^{-1}$ 7.5% grade, alternating with lifting 20 kg). Subjects were tested wearing three levels of clothing protection: combat clothing (L); combats and a semi-permeable NBC overgarment with the hood down (M); combats and NBC overgarment, gloves, boots and respirator (H). For each clothing configuration, subjects were evaluated using both a "continuous" exercise protocol and an intermittent work and rest schedule. WTT was defined as the time until rectal temperature (T_{re}) reached 39.3°C, heart

rate reached 95% maximum, dizziness or nausea precluded further exercise, or 5 h had elapsed. Assuming a resting $\dot{V}O_2$ max of 4 $kg^{-1} \bullet min^{-1}$ an average metabolic rate was calculated for all trials. A decreasing hyperbolic function described the relationship between WTT and metabolic rate for M and H. These relationships facilitate quantification of appropriate work and rest schedules if the metabolic rate of a task is known.

Tikuisis, P., & Ducharme, M. B. (1993). **Quantification of Steady State Heat Transfer in the Upper Limbs.** In R. E. Reinersten, A. O. Brubakk, & G. Bolstad (Ed.), *19th Annual Meeting of European Undersea Biomedical Society,* (pp. 71-74). Trondheim, Norway: SINTEF UNIMED.

Abstract An experiment was conducted to examine the role of convective heat transfer in the limbs by measuring the steady state heat flux at various sites on a subject's forearm and hand during its immersion in a water bath under two temperature conditions, 20 and 38°C. Heat flux was measured along the circumference of the middle finger, and at the distal, medial, and proximal portions of the forearm using 4,5,6, and 8 recalibrated heat flux transducers, respectively. Steady state was attained within 3 h of immersion and this was followed by a 0.5 h period of arterial occlusion of the forearm to ascertain the metabolic contribution from the resultant asymptotic heat flux levels. The mean measured heat fluxes (± SE) at steady state before occlusion at 20°C were 0.8 (0.3), 22.1 (5.9), 37.0 (2.8), and 69.1 (2.7) $w \bullet m^{-2}$, and at 38°C were -9.8 (2.6), -16.6 (2.0), -11.4 (1.8), and -8.6 (1.0) $w \bullet m^{-2}$ (-ve values indicate a heat gain) for the finger, distal, medial, and proximal sites, respectively. Upon removal of the metabolic contributions and conversion of the resultant convective heat transfers (includes a small longitudinal conductive component) to volumetric units denoted as *bc*, steady state values ranged from 45 (finger) to 4408 (proximal) $w \bullet m^{-3}$ for 20°C and from -824 (medial) to -3296 (distal) $w \bullet m^{-3}$ for 38°C. The highest levels of heat transfer in the forearm under both water temperature conditions occurred at sites over the major arteries; the ratio of highest to lowest heat transfers from distal to proximal forearm were 9.71, 3.65, and 1.81 for 20°C, and 3.63, 2.50, and 1.43 for 38°C. These results may be applicable for minimizing heat loss or maximizing heat recovery in the upper limbs during thermal stress.

Vallerand, A. L. (1993). **Effects of ephedrine/xanthines mixtures on thermogenesis and cold tolerance.** *Intnl. J. Obesity, 17 (Suppl. 1),* S53-S56.

Abstract This paper reviews the use of ephedrine (E) and xanthines (X) to improve thermogenesis and cold tolerance. Recent experiments in cold-exposed subjects have shown that the beneficial effect of the ingestion of an E/caffeine (C) capsule on metabolic rate (M), heat debt, body core temperature (Tc) ($P<0.05$) is entirely comparable to that observed with an E/C/theophylline (T) capsule. Although T has been reported to reduce the drop in Tc in several studies, these improvements are difficult to explain in the absence of changes in M. A theobromine-based chocolate bar (Cold Buster™) has been similarly shown to reduce the drop in Tc. However, such a claim could not be subsequently confirmed. Despite an increase in M in some studies, C had no effect on Tc in the cold. It is concluded that E/X represent at the moment, the best pharmacological agents to enhance cold thermogenesis and to delay the onset of hypothermia in humans.

Vallerand, A. L., & Jacobs, I. (1993). ***Interaction of a food supplement, intermittent exercise and cold exposure on heat balance.*** (DCIEM 93-19). Defence and Civil Institute of Environmental Medicine.

Abstract Our recent human studies do not support the theory that energy substrate mobilization is a limiting factor for cold-induced heat production (M). One possible explanation for these conflicting results is that, since our studies were performed at rest, our rates of energy substrate mobilization and M, were simply too low to exploit the effects of feeding and methylxanthines on substrate mobilization and M in the cold (Wang, et al. 1989). The goal of this study was therefore to test this hypothesis by determining whether the ingestion of a xanthine-containing food supplement in cold-exposed subjects performing intermittent exercise, increases M and thus reduces the heat debt. Eight semi-nude fasted subjects were exposed for 3h at 0°C, 0.5 $m \bullet s^{-1}$ wind (alternate 10 min walk/20 min rest periods) on two occasions following the ingestion (at min -5) of either a 300 kcal food supplement (high-carbohydrate cookie containing 100 mg of the methylxanthine, theobromine) or a placebo (relatively similar supplement without theobromine) under double-blind placebo-controlled conditions. M was increased in the cold on average by as much as 3.4 fold at rest and by 6.7 fold with exercise, compared to normal resting values at thermal neutrality. However, there were no differences due to the food supplement either at rest or during exercise. Heat debt as well as rectal and mean skin temperatures were similarly unaffected by the food supplement. Substrate oxidation was slightly altered by the ingestion of the food supplement, as indicated by a significant increase in non-protein respiratory exchange ratio ($p<0.05$), a tendency for an increase in carbohydrate oxidation and a decrease in lipid oxidation, in comparison to the placebo (n.s.). In conclusion, the present study demonstrates that even though intermittent exercise in the cold markedly increases M, ingesting energy substrates and theobromine does not offer any benefit with respect to M, heat debt or body temperatures in comparison to substrates alone. Further, it is suggested that in humans, energy substrate mobilization is not a limiting factor for the production of heat, even during intermittent exercise in the cold.

Vallerand, A. L., & Jacobs, I. (1993). ***Effects of a high-energy food supplement on cold-induced thermogenesis.*** (DCIEM 93-36). Defence and Civil Institute of Environmental Medicine.

Abstract In previous studies (Vallerand et al. 1992c, In Press; Vallerand & Jacobs 1993), we have not been able to show any influence of the ingestion of energy substrates on cold-induced thermogenesis ($\dot{M}$), in contrast to the theory that energy substrate mobilization is a limiting factor for cold-induced $\dot{M}$ in humans (Wang et al. 1986, 1987, 1989). One possible explanation for our conflicting results, is that a higher or optimal dose of energy substrates is required to observe a beneficial effect on $\dot{M}$. The goal of this study was therefore to determine whether the ingestion of a high-energy food supplement (710 kcal or 2,970 kJ) in the cold could alter: 1) M, 2) heat balance [min by min determination of heat debt ($\dot{S}$) where $\dot{S}=\dot{M}$ - heat losses, via partitional calorimetry], 3) rectal (T_{re}) and 4) mean skin temperatures ($\overline{T}_{sk}$), 5) rates of substrate oxidation and 6) plasma levels of substrates and hormones, taken as indices of substrate mobilization. Seven healthy males were subjected to two semi-nude cold exposure tests (3h at 7°C, $1\ m \bullet s^{-1}$ wind, fasting, tests performed 1 wk apart, after proper familiarization). The high-energy supplement (Ensure Plus™) was ingested in three equal drinks after 5 min, one h and two h of the 3 h test. Data were analyzed by repeated measures ANOVA. The supplement did not influence either T_{re}, $\overline{T}_{sk}$, average $\dot{M}$ (127.5±9.6 vs 129.7±10.4 $W \bullet m^{-2}$, for the supplement vs placebo respectively) or total S (22.6±1.5 vs 22.8±1.4 $kJ \bullet kg^{-1}$) in comparison to the placebo test in the same subjects. This absence of changes occurred even though the supplement increased carbohydrate mobilization (plasma

glucose and insulin levels were significantly increased) and oxidation (0.38±0.02 vs 0.50±0.06 $g \bullet min^{-1}$; +32%, P<0.05; for the placebo vs supplement, respectively) at the expense of lipid mobilization (plasma glycerol and FFA were significantly reduced) and oxidation (0.20±0.02 vs 0.14±0.02 $g \bullet min^{-1}$;for the placebo vs supplement, respectively; -32%, p<0.05). Further, the supplement was also associated with lower epinephrine levels (-40%, P<0.05) and slightly lower norepinephrine levels (-18%, n.s.) in comparison to the placebo test. The present results demonstrate that the ingestion of a food supplement that enhances energy substrate mobilization and oxidation, does not alter either cold thermogenesis, the heat debt, or body temperatures in humans, under normal conditions. Taken together with previous studies (Vallerand et al. 1992c, In Press; Vallerand & Jacobs 1993), the present results do not lend support to the theory that substrate mobilization per se is a limiting factor for cold thermogenesis in humans, even after the ingestion of as much as 710 kcal (2,970 kJ) of substrates. It is therefore recommended that other mechanisms of action regulating cold-induced thermogenesis should be investigated.

Vallerand, A. L., Tikuisis, P., Ducharme, M. B., & Jacobs, I. (1993). **Is energy substrate mobilization a limiting factor for cold thermogenesis?** *Eur. J. Appl. Physiol., 67,* 239-244.

Abstract Energy substrate mobilization has been suggested as being a limiting factor for the rate of cold induced thermogenesis (metabolic heat). The evidence supporting this hypothesis in humans however, is not convincing and the hypothesis has yet to be tested in a rigorous manner using a full heat balance analysis (partitional calorimetry). The goal of this study was therefore to re-investigate whether enhancing energy substrate mobilization by feeding cold-exposed subjects would improve metabolic heat production and affect heat debt (the minute-by-minute balance of heat production and heat losses) as well as rectal and mean skin temperatures . Nine healthy semi-nude fasted subjects were exposed to 5°C (3h at rest, 1 $m \bullet s^{-1}$ wind) on three occasions following two ingestions of either: 1) a placebo; 2) 710 kJ of pure carbohydrates (100%-CHO), or 3)710 kJ of a high carbohydrate bar (High-CHO). As expected in the cold, rectal and mean skin temperatures decreased whereas M, heat debt (S) and heat losses increased (P<0.01). However, there were no differences between treatments. During the CHO treatment, rates of carbohydrate oxidation were the highest and fat oxidation the lowest (P<0.05) whereas the Cold Buster' caused smaller changes. The results demonstrate that in the cold, enhancing energy substrate mobilization by ingesting substrates in the form of either pure carbohydrates or the Cold Buster does not cause detectable changes in M, heat loss, S or body temperatures, compared to the ingestion of a placebo. The results do not support the theory that energy substrate mobilization is a limiting factor for cold-induced thermogenesis in humans.

1994

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1994). **Effects of training and acclimation on heat tolerance in exercising men wearing protective clothing.** *Eur. J. Appl. Physiol., 68,* 234-245.

Abstract This study examined the effectiveness of endurance training and heat acclimation in reducing the physiological strain imposed by exercising in the heat while wearing protective clothing. Seven young men underwent 8 weeks of physical training (60-80% maximal aerobic power ($\dot{V}O_2$ max) for 30-45 $min \bullet day^{-1}$, 3-4 $days \bullet week^{-1}$ at < 25°C) followed by 6 days

of heat acclimation (45-55% $\dot{V}O_2$ max for 60 $min \bullet day^{-1}$ at 40°C, 30% relative humidity). Nine other young men underwent corresponding periods of control observation and heat acclimation. Before and after each treatment, subjects completed a treadmill walk (4.8 $km \bullet h^{-1}$, 2% grade) in a climatic chamber (40°C, 30% relative humidity), wearing in turn normal combat clothing or clothing protecting against nuclear, biological , and chemical (NBC) agents. Criteria for halting this test were: (1) a rectal temperature (T_{re}) of 39.3°C; (2) a heart rate (f_c) ≥ 95% of the subject's observed maximum, maintained for 3 min; (3) unwillingness of the subject to continue; (4) the elapse of 120 min. The training regimen increased mean $\dot{V}O_2$ max by 16% and mean plasma volume by 8%. When tested in normal combat clothing, the rates of increase in T_{re} and f_c were slower after training. However, when wearing NBC protective clothing, the only significant change induced by training was a higher mean skin temperature ($\overline{T}_{sk}$) in the early part of the test. Heat acclimation increased the mean plasma volume of untrained subjects by 8%, but their $\dot{V}O_2$ max remained unchanged. When tested in normal combat clothing, acclimation decreased their mean values of T_{re}, $\overline{T}_{sk}$, f_c and metabolic rate. When wearing NBC protective clothing, the only significant decrease after acclimation was in overall T_{re}. In trained subjects, heat acclimation induced no further improvements in any physiological variable when wearing normal combat clothing, but reduced overall T_{re} and $\overline{T}_{sk}$ when wearing NBC protective clothing. Training- or acclimation-induced increases of sweat secretion (an average increment of 0.14-0.23 $kg \bullet h^{-1}$) were not accompanied by any statistically significant increase in sweat evaporation when wearing NBC protective clothing. Moreover, tolerance times were unchanged in either normal combat (116-120) or NBC protective clothing (47-52 min). We conclude that neither endurance training nor heat acclimation do much to improve exercise tolerance when wearing NBC protective clothing in hot environments, because any added sweat secretion decreases blood volume and increases discomfort without augmenting body cooling.

Bain, B., Jacobs, I., & Buick, F. (1994). **Electromyographic indices of muscle fatigue during simulated air combat manoeuvring.** *Aviat. Space Environ. Med., 65,* 193-198.

Abstract Pilots exposed to high levels of headward (+Gz) acceleration must perform voluntary muscle contractions in order to maintain head-level arterial pressure. To study the possibility that muscular fatigue can limit man's +Gz duration tolerance, electromyographic (EMG) activity and EMG indices of muscular fatigue were measured during a simulated air combat manoeuvring (SACM) centrifuge profile. Eight experienced male volunteers were exposed to a +4-7Gz centrifuge profile until volitional fatigue. Electrical activity (EMG) was recorded in 7 muscles: biceps brachii (BB), latis-simus dorsi (LD), pectoralis major (PM), rectus abdominis (RA), vastus lateralis (VL), biceps femoris (BF) and gastrocnemius (GN). EMG and force during isometric contractions of the same muscles were also recorded at 1G. Root mean square (RMS) and mean power frequency (MPF) were calculated for each second of EMG data. G-tolerance time averaged 256 + 33 s (mean + SD). RMS activity was expressed relative to activity during a maximal muscle contraction. The mean values (%) for each muscle during the 7G plateau were: RA, 30.8; BB, 26.4; LD, 44.0; PM, 48.5; VL, 43.4; BF,31.4; GN, 39.3. The estimated level of contraction relative to a MVC (%) was: RA, 36.6; BB, 30.5; LD, 43.9 and PM, 61.4. There was no significant difference between contraction levels for any of the muscles studied. RMS activity did not increase over time and MPF decreased significantly only in BF and LD, however,

these decreases were small. EMG activity and estimated contraction intensities were considered to be low to moderate. These results suggest that it is unlikely that fatigue in the muscles studied would limit G-tolerance time.

Bourdon, L., Jacobs, I., & Vallerand, A. (1994). **The effects of Modafinil on heat production and regulation of body temperatures in cold exposed humans.** *Aviat. Space Environ. Med., 65,* 999-1004.

Abstract Military personnel often $\overline{T}_{sk}$ undergo sustained operations that affect vigilance and alertness. Pharmacological agents may be used to enhance vigilance. Most such agents also have thermogenic properties. Whether a new promising stimulant, modafinil (Lyons & French, Aviat. Space Environ. Med. 1991; 62: 432-435), has a beneficial effect on cold tolerance in the military context, is not known. The goal of this study was therefore to evaluate the effect of this new drug on thermal balance and the regulation of body temperatures in neutral conditions and when challenged by a cold exposure. Nine subjects underwent three trials each: two in the cold (3 h at rest, 10 °C) 0.5 h after the ingestion of either placebo or modafinil (200 mg), and one in thermal neutrality with modafinil (same conditions except T_{db} = 29.3 °C). As expected, cold produced a drop in T_{re} and $\overline{T}_{sk}$ $\overline{T}_{sk}$ and an increase in $\dot{V}O_2$. Although non-significant, there was a tendency for a slightly greater drop in T_{re} with modafinil (0.65 °C vs 0.57 °C with placebo). A similar tendency was found for the heat debt (S) which was greater with modafinil than with placebo (16.1 ± 0.7 vs 14.7 ± 0.6 $kJ \bullet kg^{-1}$, respectively, +9.5%, p=0.11). This tendency appears to be the combined result of a slightly lower mean heat production during the test and a slightly greater mean dry heat loss. When tested at thermal neutrality the drug had no effect on any thermal or metabolic parameters. The results demonstrate that the ingestion of a single dose of modafinil has no significant acute effect on thermal balance in neutral conditions and on thermoregulation in normal subjects exposed to cold. However, a tendency for slightly greater cooling was noted with modafinil. It is not known whether the use of modafinil in conjunction with sleep deprivation (a likely scenario) could magnify this effect.

Bourdon, L., Vallerand, A. L., Jacobs, I., & Bell, D. G. (1994). **Effet de la prise de psychotropes sur la tolérance à une exposition aiguë au froid chez l'homme.** *Trav. Scient., 15.*

Abstract Parmi les contraintes des opérations militaires, le froid et le manque de sommeil sont très fréquemment observés. La gestion des périodes de repos peut amener le combattant à prendre des substances psychotropes favorisant ou retardant le sommeil. Les effets de telles substances sur la tolérance au froid sont en général méconnue. Le retentissement des substances psychotropes sur la thermo-régulation est complexe; il dépend du type de contrainte thermique (chaud ou froid), de la nature de la substance, en particulier de sa spécifité d'action (directe ou non, globale ou centrale, etc), de la dose, il peut différer avec l'espéce animale (1). Il est classique de schématiser les relations entre substances psychotropes et thermorégulation ainsi: les neurostimulants sont hyperthermiants, les neuro-analeptiques sont hypothermiants (1). Le but de cette étude a été d'analyser l'effet de deux drogues psychotropes susceptibles d'être utilisées par les militaires en opérations, l'une neurostimulant (Modafinil) l'autre hypnotique (Triazolam), sur la tolérance à une exposition au froid.
Le Modafinil (Laboratoire Lafon) est un psychostimulant de découverte récente. Il a été décrit comme une substance mimant les effets des amphétamines (3); LIN et coll., (1993)

ont suggéré que l'action du Modafinil passait par les récepteurs a 1 -adrénergiques centraux, au même titre que les amphétamines bien que les voies conduisant à cet effet soient distinctes. Ces auteurs ont montré que les deux molécules entraînaient une augmentation dose-dépendante de la température encéphalique peu après leur prise. Les amphétamines ont un effet hyperthermiant en ambiance neutre our chaude (1). En ambiance froide un effet analoque n'est pas toujours retrouvé (1). Au cours de cette étude, tous les éléments du bilan thermique de sujets exposés à une ambiance froide après la prise d'un comprimé de Modafinil ont été explorés afin de mettre en évidence un éventuel effet du Modafinil sur la tolérance au froid. Le Triazolam est une benzodiazépine. C'est le principe actif de l'hypnotique le plus largement utilisé en Amérique du Nord (HALCION®, Laboratoire Upjohn), en particulier en automédication. Les benzodiazépines ne sont pas réputées avoir un retentissement important sur la thermorégulation (2). Il a cependant été décrit un cas d'hypothermie au cours d'une immersion en eau froide chez un plongeur, peu après la prise de 0,25 mg de de Triazolam (dose usuelle, communication personnelle). Il a été recherché dans cette étude si l'hypothermie observée était liée à cette molécule ou bien à d'autres facteurs restés inconnus. Pour ces deux études, l'expérimentation s'est attachée à reproduire des conditions aussi proches que possible de celles éventuellement rencontrées en situation opérationnelle.

Ducharme, M. B., & Frim, J. (1994). **Evaluation of two thermo-metal neoprenes.** In J. Frim, M. B. Ducharme, & P. Tikuisis (Ed.), *Sixth International Conference on Environmental Ergonomics.*, (pp. 66-67). Montebello, Quebec: Defence and Civil Institute of Environmental Medicine.

Abstract Recently, Yamamoto Corporation introduced on the market a new type of diving suit fabric called thermo-metal neoprene. It consists of a closed-cell neoprene with the inner cloth lining coated with metal. The metal-coated lining is claimed to act as a reflective barrier that minimizes radiative heat loss from the body and hence, improves the thermal properties of the fabric by 25% over uncoated neoprene. The objective of the present study was to verify the claims of the manufacturer by comparing the insulation of two thermo-metal neoprenes (titanium and stainless steel coated) to the current Canadian Forces Arctic diving suit neoprene (CF-N) in a dry environment at 1 atmosphere and in a wet environment under various pressures to simulate dives up to 100 m.
It was found that the thermal insulation of the two thermo-metal neoprenes tested was significantly higher than that of the CF-N in both the dry and the wet environments. The best thermo-metal neoprene, the stainless steel coated neoprene, averaged an improvement of 53-60% over the CF-N depending upon the testing environment. The insulative properties of the thermo-metal neoprenes were affected, however, by the dives, decreasing by about 12% after two dives.
It was concluded that the stainless steel thermo-metal neoprene could be a potential alternative to the current CF Arctic diving suit neoprene but further testing is needed on the long term effects of dives and aging on the insulative properties of the material.

Ducharme, M. B., Frim, J., & Bourdon, L. (1994). **Infrared tympanic thermometry: methodological considerations.** In J. Frim, M. B. Ducharme, & P. Tikuisis (Ed.), *Sixth International Conference on Environmental Ergonomics.*, (pp. 146-147). Montebello, Quebec: Defence and Civil Institute of Environmental Medicine.

Abstract Infrared tympanic thermometers (ITT) are becoming commonplace in hospitals and laboratories for routine measurement of deep body temperature. Recent studies have investigated the absolute accu-

racy of these instruments or examined their relationship with other measures of deep body temperature (e.g. oral, esophageal or rectal) during surgery or cold water immersion. The results from these studies are conflicting. The objective of the present study was to investigate the influence of methodological factors and ear canal anatomy on the ITT readings.
Sixty-six male and 29 female subjects had their right ear canal characterized for its length, its diameter, curvature, presence of ear canal or tympanum inflammation, level of obstruction by cerumen, and percentage of the field of view covered by the tympanum (at ± 5% accuracy). Following the ear examination, the right tympanic temperature was measured three times by each of the three investigators using one of three different ITT instruments (FirstTemp Genius model 3000A, Intelligent Medical Systems, CA, USA; Thermoscan model IR-1, Thermoscan Inc., CA, USA; Diatek model 9000, Diatek Inc., CA, USA) for a total of 27 readings per subject within a 15-min period. During the 15-min period, the oral temperature was also measured using a small thermistor.
The infrared sensor of an ITT will register the temperature of the aural structure that it can "see" during the measurement. Several factors have been identified in this study to significantly affect the sensor's view: the diameter of the probe tip (brand of ITT), the technique of measurement (aim and pressure), and the characteristics of the ear canal (curvature, length, and tympanic inflammation). Five subjects had an ideal ear canal for tympanic temperature measurement using an ITT (short, straight, large diameter, absence of cerumen and inflammation); the average value of (Toral - Ttymp) was down to 0.15°C for those subjects compared to 0.92°C for the pool of 95 subjects. It is concluded that unless the ITT instrument has a perfect view of the tympanum (which was the case in only 5% of our subjects), it can not provide a reliable measurement of the tympanic temperature.

Ducharme, M. B., & Tikuisis, P. (1994). **Role of blood as heat source or heat sink in human limbs during local cooling and heating.** *J. Appl. Physiol., 76*(5), 2084-2094.

Abstract The objective of the present study was to investigate the relative contribution of the convective heat transfer in the forearm and extremities to 1) the total heat loss during immersion in cold water (T_w = 20°C) and to 2) the heat gained during immersion in warm water (T_w = 38°C). The heat fluxes from the skin of the forearm and finger were continuously monitored during the 3.5 h immersion of the limb with 23 recalibrated heat flux transducers. The last 30 min of immersion were conducted with an arterial occlusion of the forearm. The heat flux values decreased during the occlusion period at T_w = 20°C and increased at T_w = 38°C for all sites, plateauing only for the finger at the tissue metabolic rate (124.8 ± 29.0 $W \cdot m^{-3}$ at Tw = 20°C, and 287.7 ± 41.8 $W \cdot m^{-3}$ at Tw = 38°C). The present study shows that at thermal steady state during immersion in water at 20°C, the convective heat transfer between the blood and the forearm's tissue is the major heat source of the tissue and accounts for 85% of the total heat loss to the environment. For the finger, however, the heat produced by the tissue metabolism and liberated by the convective heat transfer are equivalent. At thermal steady state during immersion in water at 38°C, the blood has a role of heat sink, carrying away from the limb the heat gained from the environment and to a lesser extent (25%), the metabolic and conductive heat. These results suggests that during cold stress, the convective heat transfer by the blood has a greater role than suggested by previous studies for the forearm, but a lesser role for the hand.

Ducharme, M. B., & Tikuisis, P. (1994). **Convective and metabolic heat in human fingers.** In A. S. Milton (Eds.), *Temperature Regulation: Advances in Pharmacological Sciences.* (pp. 223-228). Basel, Switzerland: Birkhauser, Verlag.

Abstract The objective was to investigate the contribution of the convective heat transfer by the blood and the tissue metabolic heat production to the heat loss or gain by the finger during a 3.5 h immersion of the forearm and hand in water at temperatures (Tw) between 20 and 40°C using arterial occlusion of the forearm for the last 30 min. The finger heat loss had decreased during occlusion at $Tw \leq 37$°C but increased at $Tw >$ 37°C. At thermal steady state prior to occlusion, the convective heat contributed between 33.3 and 93.8% of the total heat loss from the finger at $20 \leq Tw \leq 30$°C; the remaining being the tissue metabolic heat. At $38 \leq Tw \leq 40$°C, the environment contributed between 88.7 and 96.7% of the total finger heat gain; the remaining being the tissue metabolic heat.

Frim, J., & Ducharme, M. B. (1994). **Physical properties of several infrared tympanic thermometers.** In J. Frim, M. B. Ducharme, & P. Tikuisis (Ed.), *Sixth International Conference on Environmental Ergonomics.*, (pp. 144-145). Montebello, Quebec: Defence and Civil Institute of Environmental Medicine.

Abstract Infrared tympanic thermometers (ITTs) are becoming commonplace for measuring body temperature in hospitals. They are inherently safe, easy to use, fast responding, and relatively unobtrusive to the patient. There is, however, a concern over the absolute accuracy, reproducibility, and general applicability of these instruments in a research setting where more precision may be desirable. The purpose of this study was to evaluate several ITTs by comparing the correction algorithms used to convert the tympanic temperature readings into equivalent "core" readings, and by determining how a non-uniform temperature distribution within the angle of view of the ITT affects the temperature reading (during use the sensor will "see" not only the tympanic membrane but also a portion of the auditory canal). The "ear" consisted of a temperature-controlled disk positioned in front of a large isothermic background at 23°C. Algorithms were checked by recording the temperatures indicated in the various "mode" settings of the instruments as the temperature of the disk was varied between 23°C and 37°C. During this test the ITTs were held within 5 mm of the surface of the 50 mm diameter disk, and the absolute value and uniformity of the temperature across the disk was checked with an infrared thermogaphy camera. The angle of view test was conducted by recording displayed temperatures as a function of distance from the heated (30.6°C) disk, thereby altering the relative "hot" area within the field of view. Results indicated that in surface mode, regardless of the temperature of the target, all three ITTs read the temperature correctly to within 0.1°C (i.e., the resolution of the display on the instruments). However, the temperatures displayed at the other mode settings varied considerably between instruments as a function of both target temperature and mode setting, some adding as much as 1.3°C to the actual surface temperature reading. The angle of view test indicated that the instruments do, in fact, measure the average temperature of a fairly wide (50° – 90°) angle field of view.

Frim, J., Ducharme, M. B., & Brajkovic, D. (1994). **The influence of localized auxiliary heating on hand comfort during cold exposure.** In J. Frim, M. B. Ducharme, & P. Tikuisis (Ed.), *Sixth International Conference on Environmental Ergonomics.*, (pp. 128-129). Montebello, Quebec: Defence and Civil Institute of Environmental Medicine.

Abstract Military personnel are often required to perform delicate work in extreme cold (e.g., repair or maintenance of vehicles, weapons and equipment; treatment of wounds; etc.). This frequently necessitates the removal of protective mitts in favour of working with gloved or even bare hands. Exposure of the hands to such conditions can result in rapid cooling of the extremities, a loss of manual dexterity, and an increased risk of cold injury. Auxiliary heating of the hands with electrically heated gloves has been attempted in the past but has generally been unacceptable. The present study investigated the effect of torso heating on hand comfort and body heat transfer during bare-handed exposure to -15°C air, the working hypothesis being that heating the torso may result in the circulation of blood to the extremities to dissipate the extra heat. Subjects were dressed in thick-pile track suits and uninsulated Goretex combat jackets and pants (essentially the first two layers of the new CF Arctic clothing ensemble). The results showed that the application of 65-75 W of heat to the torso with an electrically heated vest was sufficient to maintain the fingers near 25°C for several hours.

Frim, J., Ducharme, M. B., & Tikuisis, P. (1994). **Proceedings of the Sixth International Conference on Environmental Ergonomics.** In J. Frim, M. B. Ducharme, & P. Tikuisis (Ed.), *Sixth International Conference on Environmental Ergonomics.*, Montebello, Quebec: Defence and Civil Institute of Environmental Medicine.

Abstract This meeting was the sixth in a series of biennial conferences that began in 1984. The meetings have been held alternately in Europe and North America and have drawn attendance from over 20 countries. These Proceedings consist of 122 two-page minipapers in the field of Environmental Ergonomics. Topics include heat physiology, cold physiology, clothing, protective equipment, measurement techniques, modeling and manikins, thermoregulation, performance, and related environmental topics. All papers were peer-reviewed by two members of a 15-person program committee from 11 countries.

Giesbrecht, G. G., Ducharme, M. B., & McGuire, J. P. (1994). **Comparison of forced-air patient warming systems for perioperative use.** *J. Anaesthesiology, 80*(3), 001-009.

Abstract Summary statement: Four forced-air warming systems were tested on nomothermic volunteers and the total heat flux was greatest with the Bair Hugger ® 250/PACU Patient Warming System. Background: Perianesthetic hypothermia is common and produces several complications, including postoperative shivering, decreased drug metabolism and clearance, and impaired wound healing. Forced-air warming transfers more than 50 W to the body and is an efficient method for either preventing or reversing decreases in core temperature. Methods: The authors compared the efficacy of four complete forced-air warming systems: (1) Bair Hugger ® 250/PACU Patient Warming System with 300 Warming Cover (Augustine Medical, Eden Prairie, MN); (2) Thermacare™ TC1000 Power Unit with TC1050 ComfortQuilt (Gaymar Industries, Orchard Park, NY); (3) WarmAir™ 130 Hypothermia System with 140 Warming Tube (Cincinnati Sub-Zero Products, Cincinnati, OH); and (4) WarmTouch™ 5000 Patient Warming System and 503-0810 CareQuilt (with the connection hose compressed [short] and extended [long]) (Mallinckrodt Medical, St. Louis, MO). Six minimally clothed male volunteers were studied supine in a 24.5°C environment. Cutaneous heat flux and skin temperature was measured at 14 area-weighted sites using thermal flux transducers. After 20-min control periods, volunteers were warmed for 40 min in each condition. A cotton blanket was placed over each cover. Power units were

placed at the foot end of the bed, started cold, and set at maximum temperature and flow settings. All units reached efficiency within 20 min.
Results: Total heat transfer with the Bair Hugger® system (95 ± 7W) was greater ($p<0.05$) than with WarmTouch™ (short hose 81 ± 6 W and long hose 68 ± 8 W), Thermacare™ (61 ± 5 W), and WarmAir™ (38 ± 6 W) systems. Each cover also was tested on a common power unit (Bair Hugger® 200). Total heat transfer was greater ($P<0.05$) with the Warming Cover (Bair Hugger®) (88 ± 8 W), followed by the Comfort Quilt (Thermacare™) (56 ± 6 W), CareQuilt (WarmTouch™) (50 ± 7 W), and the Warming Tube (WarmAir™) (43 ± 6 W).
Conclusions: The advantages of the Bair Hugger® system and Warming Cover are evident in areas that are important for heat transfer from the periphery to the body core (chest, axilla, abdomen, and upper legs).
(Key words: Equipment: thermal heat flux transducers. Hypothermia: perioperative; post-operative. Temperature: heat transfer. Temperature, regulation: warming devices.)

Jacobs, I., Allsopp, A., Goforth, H., Murray, N., Stroud, M., & Vogel, J. (1994). ***Assessment of Potential Ergogenic Aids for Elite Combat Units.*** (TTCP The Technical Cooperation Subgroup U Action Group 12.

Abstract This document constitutes the final report of TTCP Subgroup U Action Group 12 (AG 12), "Physical Performance Enhancement of Elite Combat Units." AG12's mandate was to identify and evaluate ways of enhancing the physical performance of military personnel who may have missions where a high level of physical fitness is critical to accomplishing the mission objectives. To fulfill this mandate AG12 restricted its efforts to carrying out an extensive review of available scientific literature on the topic of "ergogenic aids (EA)." EA are pharmacological and/or nutritional substances, and physiological procedures or strategies which induce an improvement of a physical fitness component(s). AG12 has also evaluated whether a purported EA might be feasibly applied to the needs of elite combat or special warfare units. Another important purpose of our review was to dispel many myths about purported EA which have been shown to be ineffective. Finally, we have also identified many potential EA which require further research before a final judgment about their efficacy can be made. The results of our review and evaluation are contained in this document. We stress to the readers of this document that it is not intended to be a "user's manual" advocating use of specific substances by a combatant, but rather a resource for scientists, medical officers, and other advisors.

Jacobs, I., Martineau, L., & Vallerand, A. (1994). **Thermoregulatory thermogenesis in humans during cold stress.** In J. Holloszy (Eds.), *Exercise and Sports Sciences Reviews.* (pp. 221-250). Baltimore: Williams and Wilkins.

Abstract

Jacobs, I., Prusaczyk, W. K., & Goforth, H. (1994). ***Adaptations to 3 weeks of aerobic/anaerobic training in West Coast US Navy Sea-Air Land Personnel (SEALs).*** (in review). Naval Health Research Center.

Abstract It is essential for some military personnel that their musculature be trained to perform over a broad range of intensities. The question thus arises whether physiological adaptations to concurrent training of contrasting physical fitness components is problematic, such as engaging in simultaneous training to develop both aerobic and anaerobic fitness. Earlier attempts to achieve concurrent improvements in different fitness components have typically involved having subjects engage in two training

programs, one for each of the fitness components being trained. Thus the studies that have demonstrated that concurrent adaptations to contrasting physical fitness variables are achievable, do not address the question of efficiency of training, because the time actually spent engaged in training was simply increased in all of these studies to accommodate the requirement to train strength and aerobic fitness, for example. This time factor can be critical for military personnel, whose training time is primarily devoted to developing and maintaining diverse operational skills an abilities.

This investigation addressed this problem by making inter-group comparisons of physiological and performance adaptations to training at various intensities. One of the training intensities was chosen with a specific view to enhancing both aerobic and anaerobic fitness in an efficient manner by training at a single exercise intensity, with full cognizance that the rate and extent of adaptations would be less than if the objective was to enhance only one of these two fitness components. The subjects in this study were recruited from US Navy Special Warfare Units and were all SEALs (SEA Air Land commandos) accustomed to hard exercise. They were divided into three groups: one group engaged in a traditional aerobic training program to develop endurance, a second group did a traditional anaerobic training program to develop explosive power and muscular endurance (anaerobic), and the third group did interval training involving both short bouts of high intensity exercise combined with low intensity recovery periods. All training and performance tests were done on bicycle ergometers. Training sessions were 30 minutes long and were scheduled three times weekly for three weeks. The results indicated that the time available for physical training can be efficiently used to simultaneously develop both aerobic and anaerobic fitness if appropriate training intensities are chosen. The results also suggest that training adaptations of both aerobic and anaerobic fitness can be more rapidly attained than traditionally expected.

Jacobs, I., Wang, L. C. H., Romet, T., Kavanagh, M., & Frim, J. (1994). ***Effects of theophylline ingestion on thermoregulation during 15°C water immersion.*** (DCIEM 94-46). Defence and Civil Institute of Environmental Medicine.

Abstract Military personnel can be exposed to emergency survival conditions in cold environments which could result in lethal levels of hypothermia if appropriate insulation or protective shelters are not available. Hypothermia can be delayed in humans if metabolic heat production is increased, and we have previously demonstrated that pre-treatment with certain safe pharmacological agents can elicit such an effect. Others have reported that the ingestion of theophylline, a caffeine-like compound, delays the onset of hypothermia during acute cold air exposure. The present study was carried out to determine if theophylline treatment will delay the onset of hypothermia during a more severe cold stress, i.e. cold water immersion. Eight male subjects were immersed in 15°C water on several different days after treatment with placebo, theophylline, or either of these combined with a standard meal. Although there were indications that the theophylline treatment, particularly when combined with the meal, increased metabolic heat production prior to immersion, there were no significant differences between trials in metabolic heat production during the water immersion. Rectal temperature decreased similarly in all trials at a rate ranging between 0.4 to 3.0°C/h. Thus, the beneficial effects of theophylline treatment that were previously reported for cold air exposure may not be applicable to cold water immersion.

Livingstone, S. D., Osczevski, R. J., Nolan, R., & Keefe, A. (1994). **Physiological Responses of Men in Sleeping Bags at -20°C.** In J. Frim, M. B. Ducharme, & P. Tikuisis (Ed.), *Sixth International Conference on Environmental Ergonomics,* (pp. 138-139). Montebello, Quebec: Defence and Civil Institute of Environmental Medicine.

Abstract A set of experiments were designed to physiologically differentiate between sleeping bags with differing amounts of insulation.

McLellan, T. M. (1994). ***Tolerance times for continuous work tasks while wearing NBC protective clothing in warm and hot environments and the strategy of implementing rest schedules.*** (DCIEM 94-62). Defence and Civil Institute of Environmental Medicine.

Abstract Canadian Forces personnel must be able to sustain operations in an environment contaminated with NBC agents. However, because of the thickness and low vapour permeability of the protective clothing ensemble, there is considerable heat strain associated with wearing full NBC protection in warm and hot environments. This report provides an updated analysis of the relationship between tolerance time while wearing the NBC clothing and the work intensity at ambient temperatures of 30°C and 40°C. The mathematical function which is used to describe this relationship defines an infinite tolerance time at a specific work intensity. If the oxygen consumption associated with this work intensity is above the oxygen consumption required for resting conditions, then implementing a specific work and rest schedule will increase the total tolerance time and the total work accomplished compared with a continuous work effort. Alternatively, if the oxygen consumption associated with an infinite tolerance time is below the value defined for a resting individual, then implementing work and rest schedules may not be the correct choice. Although tolerance time will be increased, the total amount of work that can be accomplished will decrease.

McLellan, T. M., Bell, D. G., & Dix, J. K. (1994). **Heat strain with combat clothing worn over a chemical defence (CD) vapour protective layer.** *Aviat. Space Environ. Med., 65,* 757-763.

Abstract The purpose of the present study was to quantify and compare the heat strain when a new chemical defence (CD) vapour protective layer was worn under combat clothing. Twenty-three unacclimatized males (27.1 ± 5.6 y, 80.9 ± 9.3 kg, 1.78 ± 0.05 m) were assigned to a light intermittent (L, n = 7), moderate continuous (M, n = 8) or heavy continuous (H, n = 8) exercise group. All subjects performed three trials at 40°C and 30% relative humidity wearing the current CD protective clothing over combat clothing (CD-current), the CD vapour protective layer alone (CD-vapour) or under combat clothing (CD-vapour/combats). Tolerance times were significantly different among the three clothing trials for each exercise group. For group L, tolerance time increased from 116 ± 11 min for CD-current to 208 ± 11 min for CD-vapour/combats and 289 ± 20 min for CD-vapour. For group M, tolerance time increased from 67 ± 4 min to 87 ± 5 min and to 133 ± 14 min for CD-current, CD-vapour/combats and CD-vapour, respectively. Finally for group H, respective times for CD-current, CD-vapour/combats and CD-vapour were 50 ± 4 min, 59 ± 4 min and 80 ± 7 min. Significant differences among the clothing configurations were found also for the evaporative efficiency of sweat from the clothing. Values varied from 20% to 30% for CD-current to over 80% for group L with the CD-vapour configuration. Significant differences among the clothing trials for each exercise group were observed also for heart rates, rectal and skin temperatures. In all conditions, the response during CD-vapour/combats was between CD-current and CD-vapour. Although

heat strain was reduced compared with CD-current, the improvements with CD-vapour/combats might be considered significant in an operational environment only at low metabolic rates. In contrast, the benefits of CD-vapour are evident at all metabolic rates and should be recommended for operational environments that do not require abrasion protection.

McLellan, T. M., Ducharme, M. B., & Bateman, W. A. (1994). **Influence of Ondansetron on Thermoregulation During Exercise in the Heat Wearing Combat Clothing**. *Aviat. Space Environ. Med., 65,* 35-40.

Abstract Ondansetron is a selective serotonin antagonist which has been shown to be an effective antiemetic agent for patients undergoing radiation or chemotherapy treatment. The Canadian Forces together with other NATO Countries have an interest in selecting an antiemetic agent that not only is effective in the prevention of emesis induced by chemical agents or radiation exposure, but also has minimal, if any, side effects. The purpose of this study was to examine the influence of a single 8-mg oral dose of the drug on thermoregulation during exercise in a hot (40°C, 30% relative humidity) environment. Ten unacclimatized males performed a drug and placebo trial in single-blind random order. The sessions involved walking on a treadmill at 4.8 $km \cdot h^{-1}$ with a 2% elevation for a maximum of 3 h. Subjects wore combat clothing during the trials. Total exposure time was similar for the placebo (177 ± 6 min) and drug (172 ± 11 min) trials. Also, the rate of sweat production (0.64 ± 0.1 and 0.66 ± 0.1 $kg \cdot h^{-1}$ for placebo and drug, respectively) and body heat gain (303 ± 112 and 305 ± 110 kJ for the place and drug respectively) were not different between trials. Rectal temperature increased 1.48 ± 0.40°C for the placebo and 1.47 ± 0.37°C for the ondansetron trial. Finally, there was no difference in the mean skin temperature response which increased in both conditions to 37.1 ± 0.5°C. Under the conditions of this experiment, there is no evidence to suggest that the ingestion of ondansetron influences thermoregulation in a hot environment.

McLellan, T. M., & Frim, J. (1994). **Heat strain in the Canadian Forces chemical defence clothing: problems and solutions**. *Can. J. Appl. Physiol., 19,* 379-399.

Abstract The Canadian Forces chemical defence protective clothing can induce an overwhelming strain on one's ability to regulate body temperature. Recently, a number of investigations have been completed at the Defence and Civil Institute of Environmental Medicine (DCIEM) that focused initially on understanding the interaction of metabolic rate, ambient temperature and ambient vapour pressure on the severity of heat strain associated with wearing the protective clothing. This paper presents a summary of these initial studies together with an overview of different attempts to reduce heat strain during exercise in a hot environment. Factors such as improved aerobic fitness or a period of dry heat acclimation have little, if any, benefit on tolerance time while wearing the clothing during light or moderate exercise. The best solution to the problem of heat strain remains the use of microclimate conditioning (personal cooling) and these techniques have been successfully employed for Naval and Air Force personnel. However, for our Land Forces microclimate conditioning is not feasible until a lightweight high-energy power source is developed.

Osczevski, R. J. (1994). ***Thermal Resistance of the Cheek in Cold Air.*** (DCIEM 94-47). Defence and Civil Institute of Environmental Medicine.

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Abstract Some experiments were carried out to characterize the thermal resistance of the tissues of the cheek area. Heat flow and skin temperature in cold air were measured with a heat-flux transducer. The face was uncomfortably cold when the cheek skin temperature was below 15°C and painful when the skin temperature fell below 10°C. Thermal resistance increased as skin temperature fell, reaching a maximum value of 0.07 m^2K/W at a skin temperature between 10°C and 15°C.

Rayson, M. P., Bell, D. G., Holliman, D. E., Llewelyn, M., Nevola, V. R., & Bell, R. L. (1994). ***Physical Selection Standards for the British Army Recruits: Phases 1 and 2.*** (APRE 94R036). Army Personnel Research Establishment.

Abstract The Army Personnel Research Establishment (APRE) have been tasked to devise and validate role-related, gender-free physical fitness tests, to be used to screen recruits for entry into specific employment groups in the British Army. A five-phase project has been implemented to identify and measure the most physically demanding tasks (gold standards) and to develop recruit selection tests, validated against the gold standards. This report covers phases 1 and 2 - identification of role-related tasks (RRTs), and the quantification of those RRTs. One hundred and thirty-two RRTs were identified. Sixty-four of these were analysed in the field using physiological, biochemical and psychophysiological techniques. However, 92% of these tasks proved unsuitable for use as gold standards for a number of reasons, such as their complexity and high elements of skill. The possibility of simplifying the original tasks has been examined, and components of the tasks could be used to develop adapted RRTs (ARRTs). These ARRTs would require clarification and remeasurement if they are to serve as gold standards against which to validate physical selection tests. Since many of the ARRTs are somewhat similar, they could be clustered into common soldiering tasks, which would require fewer resources, and allow for more manageable administration of the tests at recruit centres. APRE recommends this course of action.

Rayson, M. P., Holliman, D. E., & Bell, D. G. (1994). ***Physical Selection Standards for the British Army: Phase 3 Development of physical selection tests and pilot study.*** (DRA WP94006). DRA Center for Human Science.

Abstract DRA CHS was tasked by DM(A) to devise physical selection standards for the British Army. After defining and measuring the most physically demanding jobs in each employment group, four representative military tasks (RMTs) were developed as gold standards (Phase 1 and 2). These consisted of a single lift (SL), a carry (C), a repetitive lift and carry (RL), and a loaded march (LM) for which each employment group was assigned to one of three levels. CHS then had to design a battery of physical tests likely to predict performance on the RMTs (Phase 3). It was also decided that a pilot study to Phase 4 (testing trained soldiers on the RMTs and the physical tests) was necessary in order to practice measurement techniques, establish the feasibility of the procedures and reduce the battery of tests for Phase 4. Seventy male and nine female soldiers took part in the pilot study, undertaking the tasks to their appropriate level and all physical tests. All soldiers achieved their assigned level on the tasks, and all completed the maximum time on the RL and LM. Therefore no analyses could be carried out on the predictive strength of the tests for the RL and LM. However, the SL and C could be analysed, with the most powerful predictors being the 38 cm upright pull, the ILM and neck circumference for the SL, and handgrip strength, hydrodynamic lift power, and fat-free mass for the C. It was recommended that eight of the fitness tests should be

dropped from the battery due to their poor predictive power, or for safety and administrative reasons. It was also proposed that all RMTs be adapted to become maximal and progressive tests: the SL should progress in 5 or 4 kg increments to maximum; the C should be allowed to continue beyond the original five-minute end point to maximum; the work rates of the RL should be adjusted to allow a more discriminatory test; the LM should require the soldiers to carry either 15, 20, or 25 kg at a pace of 6.4 km/hr for as long as possible.

Snellen, J. W., Ducharme, M. B., & Frim, J. (1994). **Body fat affects calorimetrically measured body heat storage only during cold stress.** In J. Frim, M. B. Ducharme, & P. Tikuisis (Ed.), *Sixth International Conference on Environmental Ergonomics.*, (pp. 228-229). Montebello, Quebec: Defence and Civil Institute of Environmental Medicine.

Abstract The thermal insulation of the body has multiple "in-series" components including the skin, the subcutaneous fat, and the underlying tissues. The objective of this study was to investigate for a large range of air temperatures (12 – 35°C) the contribution of body fat to the changes in body heat storage measured by direct air calorimetry. Subjects were exposed to the calorimeter temperature for three hours while wearing only shorts. Every minute the sum of metabolic heat production, sensible (R+C) heat exchange, and evaporative heat loss (E) was determined and converted to heat loss or gain in kilojoules. This in turn was divided by body mass times specific heat to obtain change in mean body temperature (ΔTb). Every subject showed a linear relationship between calorimeter temperature and ΔTb. At the colder calorimeter temperatures ΔTb was heavily dependent on body fat, with leaner subjects showing a greater drop in ΔTb than the fatter subjects; however, at higher temperatures, this dependence upon body fat disappeared. These results are consistent with the finding that at temperatures >20°C the non-fatty tissue of leaner subjects can contribute significantly to whole body insulation.

Stroud, M. A., Holliman, D. E., Bell, D. G., Green, A. L., MacDonald, I. A., & Greenhaff, P. L. (1994). **The effect of oral creatine supplementation on respiratory gas exchange and blood lactate accumulation during steady-state incremental treadmill exercise and recovery in man.** *Clinical Science, 87,* 707-710.

Abstract 1. Oral creatine supplementation has been shown to increase muscle creatine and phosphocreatine concentrations with consequent benefits on performance during short-term maximal exercise. However, recently there have been anecdotal reports that creatine supplementation can also influence the pattern of substrate utilization and improve performance during more prolonged, submaximal exercise, which, based on recent experimental evidence, may have some scientific justification.
2. Eight men performed a continuous incremental exercise test running at 10km/h on a motorized treadmill at predetermined workloads from 50% to 90% of maximal oxygen uptake, before and after 5 days of creatine supplementation (4 x 5g daily). Exercise was performed for 6 min at each workload to achieve a steady state, and respiratory gas exchange and blood lactate concentrations were measured during the last 30s at each workload. Measurements were also made at 5-min intervals for the first 15 min of recovery.
3. The results showed no measurable effect of creatine supplementation on respiratory gas exchange and blood lactate concentrations during either incremental submaximal exercise or recovery. This suggests that creatine supplementation does not influence substrate utilization during and after this type of exercise.

Tikuisis, P., & Frim, J. (1994). ***Prediction of survival time in cold air.*** (DCIEM 94-29). Defence and Civil Institute of Environmental Medicine.

Abstract The prediction of survival time *(ST)* for cold exposure is somewhat hypothetical since controlled data of deep hypothermia are unavailable. At best, case histories of accidental exposure can be used for guidance. This study describes the development of a simple heat conduction model for the prediction of *ST* under sedentary conditions in the cold. Predictions are not made for cold injury nor for the injured individual. The model is based on steady-state heat conduction in a single cylinder comprised of a core and two annular concentric shells representing the fat plus skin and the clothing plus still boundary layer, respectively. The ambient condition can be either air or water; the distinction is made by assigning different values of insulation to the still boundary layer. Metabolic heat production (*M*) is predicted by temperature signals from the core and skin, but is not allowed to exceed heat loss. Where the cold exposure is too severe for *M* to balance heat loss, *ST* is largely determined by the heat conduction characteristics of the model. Where a balance occurs, *ST* is governed by the depletion time of the energy reserve for shivering. End of survival is marked by the core temperature reaching a value of 30°C, although the model is capable of predicting lower body temperatures. Model predictions for cold water (0 to 20°C) immersion agree with the values reported by Molnar (1946) and Veghte (197'2). A sampling of *ST* predictions for nude exposure in relatively calm (1 km/h wind) cold air of an average healthy male are the following: 3,5,10, and > 24 h for-20, -10, 0, and 10°C, respectively. With 2 clo of insulation in 10 km/h wind, *ST*s are 7, 10, 17, and > 24 h for -50, -40, -30, and -20°C. The predicted *ST*s must be weighed against the extrapolative nature of the model. At present, it would be prudent to use the predictions in a relative sense, that is, to estimate the benefit of increasing one's insulation in terms of percentage increase in *ST*. Clearly, model predictions are subject to fine adjustments as more information becomes available for calibration.

Vallerand, A., & Jacobs, I. (1994). **High-energy food supplement, energy substrate mobilization and heat balance in cold-exposed humans.** In A. S. Milton (Eds.), *Temperature Regulation.* (pp. 351-356). Basel, Switzerland: Birkhäuser Verlag.

Abstract It is hypothesized that our inability to confirm that energy substrate mobilization is a limiting factor for cold-induced thermogenesis (M) in humans is due to a sub-optimal dose of ingested substrates. This hypothesis was tested in healthy males exposed twice to the cold (3h at 7°C, 1 m/s wind, nude, fasting) following the ingestion of either a placebo or a high-energy food supplement (710 kcal or 2,970 kJ). The supplement did not influence body temperatures, M or heat debt, even though it enhanced carbohydrate mobilization and oxidation (P,).05), albeit at the expense of lipid mobilization and oxidation ($p<0.05$). The results suggest that, under normal conditions, energy substrate mobilization per se is not a limiting factor for M in humans.

1995

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1995). **Skin temperatures during exercise in the heat; effects of training, heat acclimation, and protective clothing.** *(submitted for publication),* .

Abstract This study examined the influence of endurance training and heat acclimation on skin temperatures during prolonged exercise in the heat while wearing normal clothing and clothing with a limited perme-

ability. In the first experiment (Exp. 1), seven young men (T_{ET+HA}) underwent 8 weeks of physical training (60-80% $\dot{V}O_2$ max for 30-45 min • day^{-1}, 3-4 days • week^{-1} at < 25°C db) followed by 6 consecutive days of heat acclimation (45-55% $\dot{V}O_2$ max for 60 min • day^{-1} at 40°C db, 30% rh). Nine other young men (T_{C+HA}) underwent corresponding periods of control observation and heat acclimation. In the second experiment (Exp. 2), eight young men (T_{HA6}) were heat-acclimated for 6 consecutive days, and eight other young men (T_{HA12}) for 12 days (two 6-day periods, separated by a 1-day rest period). Before and after each treatment, subjects completed a bout of treadmill exercise (20 min at 1.34 m • s^{-1}, 2% grade in Exp. 1; 15 min at 1.34 m • s^{-1}, 0% grade in Exp. 2) in a climatic chamber (40°C db, 30% rh), wearing in turn normal or protective clothing. Training increased the plasma volume of T_{ET+HA} subjects by 8%. When tested in normal clothing, the overall heart rate (HR) was decreased by 9-13 beats • min^{-1} after training. When wearing protective clothing, mean skin temperature ($\overline{T}_{sk}$) was higher after training (+ 1.2°C at rest to 0.5°C at 15 min of exposure). Heat acclimation increased the plasma volume of T_{C+HA} subjects by 8%. When tested in normal clothing, acclimation reduced overall rectal temperature (T_{re}) by 0.2-0.3°C and slowed the rate of increase in HR. When wearing protective clothing, the T_{re} was again lower by 0.2-0.3°C after acclimation. In subjects, heat acclimation induced no further change in any physiological variable when wearing normal clothing, but decreased overall $\overline{T}_{sk}$ by 0.2-0.5°C and T_{re} by 0.2-0.3°C when wearing protective clothing. In T_{HA6} subjects, 6 days of heat acclimation caused a 0.1-0.2°C reduction in overall T_{re} when wearing normal clothing. In T_{HA12} subjects, a 12-day acclimation reduced overall HR by 7-11 beats • min^{-1} when wearing normal clothing and T_{re} by 0.1-0.2°C when wearing protective clothing. There was no influence of acclimation length on $\overline{T}_{sk}$, T_{re} or HR responses when wearing either type of clothing. The results (increased $\overline{T}_{sk}$ with unchanged T_{re} or unchanged $\overline{T}_{sk}$ with decreased T_{re}) suggest that by expanding plasma volume, both endurance training and heat acclimation allow an increase in skin blood flow during prolonged exercise in the heat, this being more pronounced when wearing protective clothing.

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1995). **Residual analysis in the determination of factors affecting the estimates of body heat storage in clothed subjects**. *Eur. J. Appl. Physiol., (submitted for publication).*

Abstract Body heat storage can be estimated by calorimetry (from heat gains and losses) or by thermometry (from changes (Δ) in mean body temperature ($\overline{T}_b$) calculated as a weighted combination of rectal (T_{re}) and mean skin temperatures ($\overline{T}_{sk}$). If an invariant weighting factor of T_{re} and $\overline{T}_{sk}$ is used (for instance, $\Delta\overline{T}_b = 0.8\Delta T_{re} + 0.2\Delta\overline{T}_{sk}$ under hot conditions), body heat storage could be over- or underestimated substantially relative to calorimetry, depending on whether the subject was wearing light or protective clothing. This study investigated whether any discrepancy between calorimetry and thermometry arose from methodological errors in the calorimetric estimate of heat storage, from inappropriate weightings in the thermometric estimate, or from both. Residuals of calorimetry vs. thermometric estimates were plotted against individual variables in the standard heat balance equation, applying various weighting factors to T_{re} and $\overline{T}_{sk}$. Whether light or protective

clothing was worn, the calorimetric approach generally gave appropriate estimates of heat exchange components and thus heat storage. One exception was in estimating latent heat loss from sweat evaporation. If sweat evaporation exceeded 650 $g \bullet h^{-1}$ when wearing normal clothing, evaporative heat loss was overestimated and thus body heat storage was underestimated. Nevertheless, if data beyond this ceiling are excluded from analyses, the standard 4:1 weighting matched calorimetric heat storage estimates quite well. When wearing protective clothing, the same 4:1 weighting approximated calorimetric heat storage with errors of ~ 10%, but only if environmental conditions allowed a subject to exercise for > 90 min. The best thermometric estimates of heat storage were provided by using two sets of relative weightings, based upon the individual's metabolic heat production (M in $kJ \bullet m^{-2} \cdot \bullet h^{-1}$): {4 - [(M - χ) $\bullet$ χ^{-1}] $\bullet$ 2}:1 for an initial, thermoneutral environment and {4 + [(M - χ) $\bullet$ χ^{-1}] $\bullet$ 5}:1 for a final, hot environment; the optimal value of χ lies between 450 and 500 $kJ \bullet m^{-2} \cdot \bullet h^{-1}$. We conclude that the accuracy of thermometric estimates of heat storage can be improved by modifying weighting factors of T_{re} and $\overline{T}_{sk}$ according to environment, type of clothing, and metabolic rate.

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1995). **Determination of body heat storage in clothing: calorimetry vs. thermometry.** *Eur. J. Appl. Physiol., (in press).*

Abstract Two methods of estimating body heat storage were compared under differing conditions of clothing, training, and acclimation to heat. Six male subjects underwent 8 weeks of physical training (60-80% of maximal aerobic power ($\dot{V}O_2$ max) for 30-45 $min \bullet day^{-1}$, 3-4 $days \bullet week^{-1}$ at < 25°C db) followed by 6 consecutive days of heat acclimation (45-55% $\dot{V}O_2$ max for 60 $min \bullet day^{-1}$ at 40°C db, 30% rh). Nine other males underwent corresponding periods of control observation followed by heat acclimation. Before and after each treatment, subjects walked continuously on a treadmill (1.34 $m \bullet s^{-1}$, 2% grade) in a climatic chamber (40°C db, 30% rh) for an average of 118 min (range 92-120) when wearing normal light combat clothing and for an average of 50 min (range 32-68 min) when wearing protective clothing resistant against nuclear, biological and chemical agents. The heat storage was determined calorimetrically (by the balance of heat gains and losses) and thermometrically (by the conventional equations, using one or two set(s) of relative weightings for the rectal temperature (T_{re}) to mean skin temperature ($\overline{T}_{sk}$) of 4:1 and 4:1, or 2:1 and 9:1 in thermoneutral and hot environments, respectively). $\overline{T}_{sk}$ was calculated from 12-site measurements, weighted according to the regional distribution of body surface area and the first eigenvectors of principal component analysis. There were only minor differences (< 5%) between the heat storage values calculated by given weighting factors for T_{re} and $\overline{T}_{sk}$, whether the individual coefficients were derived from estimates of regional surface area or principal component methodologies. When wearing normal clothing, no significant differences were found between the two estimates of heat storage (calorimetry vs. thermometry with an invariant relative weighting of 4:1) in any experimental condition, with one specific exception: when wearing protective clothing, thermometry underestimated heat storage by 24-31%. This underestimation was attenuated by using two sets of relative weightings of 2:1 and 4:1 or 2:1 and 9:1. The results suggest that when subjects wearing protective clothing are transferred from thermoneutral to hot environments, the accuracy of thermometric estimates of heat storage can be improved by using two sets of weighting factors for T_{re} and $\overline{T}_{sk}$.

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1995). **Heat acclimation and heat tolerance in exercising men wearing protective clothing: influence of metabolic rate and acclimation length.** *Eur. J. Appl. Physiol., (in press).*

Abstract This study investigated the influence of 6 vs. 12 days of heat acclimation on the tolerance of low-intensity exercise in the heat while wearing protective clothing. Sixteen young men were acclimated by treadmill walking (50% $\dot{V}O_2$ max for 60 $min \bullet day^{-1}$) in a climatic chamber (40°C db, 30% rh) for either 6 consecutive days or two 6-day periods, separated by 1-day rest. Before and after heat acclimation, the subjects performed a heat-exercise test (1.34 $m \bullet s^{-1}$, 0% grade; 40°C db, 30% rh), either under control conditions (wearing normal light combat clothing (continuous exercise; n = 5)) or wearing protective clothing resistant against nuclear, biological and chemical agents (repeated bouts of 15-min walk + 15-min rest; n = 8). Criteria for halting the test exercise were a rectal temperature (T_{re} of 39.3°C, a heart rate (HR) ≥ 95% of the subject's observed maximum, unwillingness of the subject to continue, or the elapse of 150 min. Heat acclimation decreased overall test values of T_{re}, HR, and mean skin temperature for both control and protective clothing conditions. When wearing normal clothing, acclimation responses were about twice as large after 12 than after 6 days, but the response was not increased by longer acclimation when wearing protective clothing. Both 6 and 12 days of acclimation increased tolerance times in protective clothing by about 15 min (from 97 ± 4 to 112 ± 6 min and from 108 ± 10 to 120 ± 10 min for 6 and 12 days, respectively). We conclude that the physiological strain and limitation of heat-exercise tolerance imposed by wearing protective clothing are not reduced if heat acclimation is prolonged from 6 to 12 days.

Aoyagi, Y., McLellan, T. M., & Shephard, R. J. (1995). **Determination of body heat storage: how to select the weighting of rectal and skin temperatures for clothed subject.** *Eur. J. Appl. Physiol., (submitted for publication).*

Abstract Two methods of estimating body heat storage were compared under differing conditions of clothing and acclimation to heat. Sixteen male subjects underwent 6 consecutive days or two 6-day periods, separated by a 1-day rest period of heat acclimation, exercising 60 $min \bullet day^{-1}$ at 45-55% of maximal aerobic power in a hot, dry environment (temperature 40°C db; relative humidity 30%; and wind speed 0.3 $m \bullet s^{-1}$,). Before and after acclimation, the subjects wearing either normal light combat clothing or clothing protective against nuclear, biological and chemical agents walked on a treadmill at 1.34 $m \bullet s^{-1}$,, 0% slope in the same environment continuously (n = 11 for normal clothing) or as repeated 15-min bouts of exercise followed by 15-min sitting rest (n = 5 for normal clothing and n = 16 for protective clothing). Average exposure times were 147 min (pre-acclimation) and 150 min (post-acclimation) for continuous exercise and 150 min (both pre- and post-acclimation) for intermittent exercise while wearing normal clothing, and 103 min (pre-acclimation) and 116 min (post-acclimation) for intermittent exercise while wearing protective clothing. Heat storage was determined calorimetrically (from heat gains and heat losses) and thermometrically (using various weightings of rectal temperature (T_{re}) and mean skin temperature ($\overline{T}_{sk}$). There were only minor (< 5%) differences of estimated heat storage, whether calculations used a single specific heat (3.47 $kJ \bullet kg^{-1} \bullet °C^{-1}$) or a value computed according to the subject's body composition. When wearing normal clothing, a formula with an invariant relative weighting for T_{re} to $\overline{T}_{sk}$ of 4:1 provided the best thermometric estimate of heat storage. When

wearing protective clothing, the invariant relative weighting of 4:1 underestimated heat storage by 2-12%; underestimation was attenuated by using respective relative weightings for a thermoneutral and hot environment of 2:1 and 2:1 or 4:1 and 9:1 before acclimation and 4:1 and 9:1 after acclimation. We conclude that the accuracy of thermometric estimates of heat storage can be improved by modifying the weighting factors according to environment, acclimation, and type of clothing.

Bourdon, L., Vallerand, A., Jacobs, I., & Bell, D. G. (1995). **The effects of triazolam on responses to cold water immersion in humans.** *Aviat. Space Environ. Med., (in press).*

Abstract Managing alertness of soldiers during sustained operations is a serious source of concern for military unit commanders. A frequently employed strategy is to induce sleep before an operation, especially operations requiring prolonged travel. Sleep-inducing drugs could have an action on thermoregulation through their effect on alertness and a possible direct effect on the brain. The goal of this study was therefore to evaluate the effect of a commonly prescribed triazolam (Halcion®) on thermoregulatory responses to cold-water immersion. Eight subjects were immersed twice in 18°C water for up to 90 min in the morning; once after ingesting 0.25 mg triazolam (TRZ) the prior evening, and again after placebo (PLB) treatment. There were no significant differences between trials for mean duration of the immersion, the change in rectal temperature and mean skin temperature. Total metabolic heat production was similar for both conditions: 767 ± 107 vs. 781±105 kJ•m^{-2} for TRZ and PLB, respectively. The results should be considered in light of a large variation among the subjects in sensitivity to TRZ, which was unrelated to biometrical characteristics such as surface area-to-mass ratio, lean body mass, % body fat, physical fitness. Although not statistically significant, there was a trend for a smaller increase in plasma free fatty acid and glycerol concentrations after water immersion with TRZ. The results suggest that the ingestion of a single dose of Halcion 11 h prior to a cold-water immersion is not likely to accelerate the rate of onset of hypothermia. Individual sensitivity, however, may predispose some sensitive subjects to negative effects in this regard.

McLellan, T. M. (1995). **Heat tolerance following acclimation to the microenvironment of NBC protective clothing.** *Aviat. Space Environ. Med., (submitted for publication).*

Abstract The purpose of the present study was to compare heat tolerance while wearing nuclear, biological and chemical (NBC) protective clothing following a hot-wet (HW), hot-dry (HD) or cool-wet (CW) heat acclimation protocol. Twenty-nine males were assigned to groups HW (n = 7), HD (n = 8), CW (n = 7) or control (C, n = 7). Peak $\dot{V}O_2$ which averaged 48 - 50 ml • kg^{-1} • min^{-1} was not different among the groups. Groups HW, HD and CW completed 12, 60-min heat acclimation sessions wearing the NBC clothing (HW and CW) or shorts and a t-shirt (HD) at 40°C, 30% relative humidity (HW and HD) or 22°C, 45% relative humidity (CW). Before and after the acclimation or control period, subjects were evaluated at 40°C and 30% relative humidity during intermittent exercise (15 min of walking at 1.33 m • s^{-1} and 15 min seated rest) while wearing the NBC protective clothing. Heat tolerance trials continued until rectal temperature (T_{re}) reached 39.3°C, heart rate reached or exceeded 95% of an individual's maximum for 3 min, nausea or dizziness precluded further exercise, the subject asked to be removed from the chamber, or 150 min elapsed. Lower T_{re}, $\overline{T}_{sk}$ and heart rates were observed after the acclimation period only for group HW compared

with C. Lower $\overline{T}_{sk}$ and heart rates were found also for CW compared with C. Sweat evaporation from the protective clothing increased 30 and 20 $g \bullet h^{-1}$ for HW and CW, respectively, whereas no change was found for HD. There was no difference among the groups for the significant increase in tolerance time observed following the acclimation or control period. Mean values increased from 104 to 130 min for HW, 109 to 120 min for HD, 88 to 108 min for CW and 115 to 128 min for C. It was concluded that the most significant changes in T_{re}, $\overline{T}_{sk}$ and heart rate while wearing the NBC protective clothing in a hot-dry environment will occur following heat acclimation that involves wearing the clothing during exercise in the hot environment. Some improvements in these dependent measures can be achieved also by wearing the NBC clothing during exercise in a cool environment. Minimal improvements in heat tolerance while wearing the protective clothing should be expected following heat acclimation that does not involve exposure to the microenvironment of the clothing.

McLellan, T. M., Cheung, S. S., & Jacobs, I. (1995). **Variability of time to exhaustion during submaximal exercise.** *Can. J. Appl. Physiol., 20,* 39-52.

Abstract Exercise time to exhaustion (TE) is used commonly to evaluate the success or failure of such treatments as endurance training programs or nutritional supplements. The present study determined the variability of TE during submaximal exercise at 80% $\dot{V}O_2max$. Fifteen males performed cycle exercise to exhaustion on 5 occasions at the same time of day with a minimum of 72 h between sessions. There was no difference in TE ($0.1 > p > 0.05$) among the trials with values ranging from 14.4 ± 1.1 min for test 1 to 18.2 ± 2.4 min during the final test. Substantial variability in TE over the 5 trials was observed among subjects with coefficients of variation (CV) ranging from 2.8 to 31.4%. Subjects were divided into 2 groups using the median CV for TE. For the low CV group (n = 8), TE was significantly increased during test 3 (14.9 ± 1.3 min) compared with test 1 (12.8 ± 1.0 min) and test 5 (12.5 ± 1.2 min). For the high CV group (n = 7), TE was increased during test 5 (24.7 ± 3.7 min) compared with the other tests (18.5 \(+- 2.2 min). CV for $\dot{V}O_2$, $\dot{V}_E$, pH, PCO_2 and rectal temperature were less than 5% and did not differ between groups. Post-hoc power calculations revealed that if all subjects were considered as one group, sample size would have to increase to 40 to increase the power to 0.8. Due to the variability in TE that may be observed with males of average fitness, it is concluded that TE should not be the only dependent measure used to evaluate treatment effects during submaximal exercise.

Osczevski, R. J. (1995). **Water Vapor Transfer Through a Hydrophilic film at Sub-zero Temperatures.** *Textile Research Journal, (in press).*

Abstract The rate at which water vapor diffused through the hydrophilic component of Gore-Tex™ II was measured at temperatures ranging from -24°C to just below the freezing point of water. Although the permeability of this material increased exponentially with temperature, at sub-zero temperatures, water vapor transfer was still only a few percent of what it would normally be at room temperature. Other hydrophilic films and coatings used in outdoor clothing are likely to be similarly affected. The diffusion process in such materials is briefly discussed.

Osczevski, R. J. (1995). **The Basis of Windchill.** *Arctic, (in press).*

Abstract The wind-chill index has long been used as a gauge of the severity of winter weather. It has remained popular,

despite severe scientific criticism, because it works. How it can work when it has been shown to be faulty has not previously been explained. A model of heat transfer from a frostbite susceptible area of the face suggests that the wind-chill index is proportional to the actual heat transfer. Therefore, any wind-chill index always produces the same skin temperature on the face. This is the link between wind-chill index and thermal comfort, for the temperature of the exposed skin defines how cold the environment feels, at least in the short term. Analysis of wind-chill equivalent temperatures shows that the concept is flawed and improperly used. A new definition is suggested.

Osczevski, R. J. (1995). **Comments on "Windchill".** *Bulletin of the American Meteorological Society, .*

Abstract Examines the intent and success of the original wind-chill formula. Several alternative ways of expressing the effect of wind and temperature on comfort are described.

Osczevski, R. J. (1995). **Trial By Adventure.** In N. H. Collins (Ed.), *International Conference on Cold Weather Military Operations,* Burlington, VT: US Army Cold Regions Research and Engineering Laboratory.

Abstract In combat, cold injuries caused by inadequate protective clothing appear in numbers that are not usually seen in peacetime trials and exercises. Between 1986 and 1989, several experiments were carried out to examine a trial concept to provide a more rigorous peacetime test of equipment. A travelling system including an insulated tent, clothing and sleeping bag was developed to enable a small group to be self-supported for many days and to cover distances on the order of 1000 miles across open country, on snowmobiles. Two trials are described and the performance of the equipment and the success of the trial concept are discussed.

Rayson, M. P., Davies, A., & Bell, D. G. (1995). **Heart Rate and Oxygen Uptake Relationship: A Comparison of Loaded Marching and Running in Women.** *Eur. J. Appl. Physiol., (in press).*

Abstract Heart rate ($beat \bullet min^{-1}$) (f_c) measured during marching with a load is often used to predict the oxygen cost ($l\ min^{-1}$) ($\dot{V}O_2$) of the activity. The prediction comes from the $f_c / \dot{V}O_2$ relationship determined from laboratory measures of f_C and $\dot{V}O_2$ during treadmill running. Data from the literature suggest that this may not be appropriate in males and has yet to be examined in females. This study, therefore, compared $f_c / \dot{V}O_2$ relationship between loaded marching and maximal running protocols in females. Sixteen female subjects age 21.9 (2.3) yrs, height 1655 (58) mm, weight 62.6 (7.6) kg had their f_C (from 3-lead chest electrodes) and $\dot{V}O_2$ measured first during standard treadmill run protocols, and again one week later during loaded marching protocols. The slopes and intercepts determined from linear regression of f_C on $\dot{V}O_2$ for each individual for each protocol were compared as were the maximal heart rates (f_{cmax}), $\dot{V}O_2$ and Ratings of Perceived Exertion (RPE) from the last work period of each protocol in paired t-tests. The $f_c / \dot{V}O_2$ slopes ($p<0.01$) and intercepts ($P<0.05$) differed significantly between loaded marching and running. F_{cmax} for loaded marching were 90% of f_{cmax} for running ($P<0.01$) and $\dot{V}O_{2peak}$ for loaded marching were 80% of those running ($p<0.01$). However, RPE at the final levels for the two protocols were not significantly different. The data suggest that in women

the $f_c / \dot{V}O_2$ relationships for loaded marching and for running are different. This difference is similar to that found in men when speed is held constant and the load and gradient are varied. The results suggest that it would be erroneous to use f_c and $\dot{V}O_2$ measured during running protocols in the laboratory to estimate energy expenditure and work intensity during loaded marching in the field.

Vallerand, A., Zamecnik, Y., & Jacobs, I. (1995). **Effects of cold stress on plasma glucose turnover in humans.** *J. Appl. Physiol., (in press).*

Abstract To clarify the source of increased carbohydrate oxidation during cold stress, six males rested for 3h at 29°C and at 10°C dressed only in shorts. After priming the blood glucose and bicarbonate pools, U-$^{13}C_6$-glucose was infused for 3h in each condition to determine the plasma glucose rate of appearance (R_a) or turnover, under relative steady-state conditions. Plasma enrichment (mole per cent excess) was determined by selective ion monitoring gas-chromatography mass-spectrometry. Cold exposure decreased rectal temperature, mean skin temperature and increased heat debt, metabolic rate, whole body lipid and carbohydrate oxidation (CHO_{ox}), compared to the same subjects at thermal neutrality ($P<0.05$). Cold exposure significantly increased R_a from 13.1±0.6 to 16.2±0.4 $\mu mol \bullet kg^{-1} \bullet min^{-1}$ ($P<0.05$). Plasma glucose clearance was elevated commensurately by the cold (from 2.68±0.15 to 3.55±0.14 $\mu mol \bullet kg^{-1} \bullet min^{-1}$; $P<0.05$). Assuming that Ra is completely oxidized (thus equivalent *to maximum* rates of plasma glucose oxidation, R_{ox}), *the minimum* rates of glycogen and lactate oxidation in the cold would be the difference between CHO_{ox} and R_{ox}, about 14.0±3.0 $\mu mol \bullet kg^{-1} \bullet min^{-1}$. Therefore, under the present laboratory conditions, 54% of CHO_{ox} would be fuelled by plasma glucose oxidation whereas the remaining 46% would be derived from the combination of glycogen and lactate oxidation. The results of the present study demonstrates that cold exposure in men enhances the turnover and metabolic clearance of plasma glucose. The results also suggest that carbohydrate oxidation during cold stress appears to be about equally divided between the oxidation of plasma glucose and the combination of lactate and intramuscular glycogen.

EXPERIMENTAL DIVING UNIT

51CD

Diving

1986

Eatock, B. C., & Nishi, R. Y. (1986). ***Procedures for Doppler Ultrasonic Monitoring of Divers for Intravascular Bubbles.*** (DCIEM 86-C-25). Defence and Civil Institute of Environmental Medicine.

Abstract Doppler ultrasonic detection of intravascular bubbles is a routine procedure for several laboratories engaged in decompression research. This technical communication recommends standard procedures to be followed in using the Doppler technique. The choice of monitoring sites is discussed. The two cases for observation, rest and movement, are described, and recommendations for scheduling the observations are given. Hints for making good, well-documented tape recordings of the Doppler signal are included. The K-M Code for describing the results is explained, and recommendations for the information that should be stored in records are given. Some difficulties in interpreting signals are discussed.

Eatock, B. C., & Nishi, R. Y. (1986). ***Doppler Ultrasonic Detection Of Intravascular Bubbles During Decompression From The 1985 CAN/UK Saturation Dives To 100 And 360 MSW.*** (DCIEM 86-R-10). Defence and Civil Institute of Environmental Medicine.

Abstract Four Royal Navy divers were monitored using Doppler ultrasound for intravascular bubbles during decompression from two saturation dives done at the Dive Research Facility at DCIEM. The depths of the dives were 100 msw and 360 msw, and the breathing gas was oxy-helium. The object of the monitoring was to provide diagnostic information to the diving medical officers responsible for the divers' welfare, and to collect information on the safety of the decompression profiles. The divers were monitored twice daily throughout the decompressions. In the first dive, no bubbles were detected at any time. In the second dive, bubbles were detected in all subjects around the depth of 100 msw, before a scheduled reduction in ascent rate from 1.5 msw per hour to 1.0 msw per hour. In two of the subjects, the bubbles were numerous. Throughout most of the rest of the decompression, few bubbles were detected.

Hamilton, K., Fowler, B., & Porlier, G. (1986). **A study on the effects of nitrogen narcosis on diver performance.** In *Proceedings of the 19th Annual Meeting of the Human Factors Association of Canada.* (pp. 67-70). Vancouver, B.C.: Human Factors Association of Canada.

Abstract A number of studies have used nitrous oxide to investigate nitrogen narcosis in humans at the surface. However, it has not been clearly established that nitrous oxide and hyperbaric air produce identical effects on behaviour. Accordingly, two experiments were conducted to ascertain if the effects of alcohol (ALC=1.5 mg/kg) and dextroamphetamine (DEX=15 mg) in combination with hyperbaric air were comparable to those obtained with nitrous oxide in previous surface studies. In each experiment, 8 subjects performed a serial 2, 3 and 4 choice-reaction time task at a pressure of 6.4 ATA. The results indicated that ALC adds to the impairment produced by narcosis and DEX has an ameliorating effect. These findings confirm the hypothesis that hyperbaric air and nitrous oxide produce equivalent qualitative effects on behaviour, probably through the sane mechanisms. The present study also demonstrates the validity and practicality of using nitrous oxide to investigate the effects and causes of inert gas narcosis in humans safely and economically on the surface.

Hamilton, K., Porlier, G., Landolt, J., Fraser, W., & Fowler, B. (1986). **Effects of inert gas narcosis on the vestibular ocular reflex.** *Undersea Biomed. Res., 13*(3), 355-359.

Abstract A study was conducted to examine the vestibular ocular reflex (VOR) during narcosis. The slow phase velocity of the nystagmus was measured in six subjects by means of electronystagmography during the inhalation of 25% nitrous oxide. It was found that nitrous oxide increased the velocity of the slow phase component of the VOR by approximately 50%. This result indicates that the gain of the VOR is effectively increased during nitrous oxide induced narcosis. It appears that the vestibular end organs and/or the central pathways controlling nystagmus are affected by nitrous oxide and this may be a reason for the disruption in balance associated with inert gas narcosis.

Hobson, B. A., Henderson, D. L., Grodski, J. J., & Allin, L. V. (1986). ***CAN/UK SAT-DIVES 1 & 2/85: Operation Summary Report.*** (DCIEM 86-R-21). Defence and Civil Institute of Environmental Medicine.

Abstract The Canadian Experimental Diving Division, in conjunction with the Admiralty Research Establishment, Physiological Laboratory agreed to conduct two Helium/Oxygen (HeO2) Saturation Dives to depths of 100 msw and 360 msw in the Diving Research Facility (DRF). These dives were conducted under the auspices of the Canada/United Kingdom Memorandum of Understanding (CAN/UK MOU) on Human Undersea Program and they were formally designated CAN/UK SAT-DIVE 1/85 and CAN/UK SAT-DIVE 2/85. The aim of SAT-DIVE 1/85 was basically training while the aim of SAT-DIVE 2/85 was to complete a series of equipment performance evaluations enroute to and while at 360 msw. These evaluations looked at 3 types of equipment; a divers gas recirculating system, different types of diver thermal protection suits, and diver monitoring equipment. SAT-DIVE 2/85 consisted of 4 days of compression, 8 days at 360 msw and 16 days of decompression. Over the period of the dive all objectives were successfully met.

Nishi, R. Y. (1986). ***Altitude-Corrected Air Diving Decompression Tables and Modified Treatment Tables for CFSAT (Canadian Forces School of Aeromedical Training), Edmonton.*** (DCIEM 86-C-20). Defence and Civil Institute of Environmental Medicine.

Abstract Decompression tables designed for use at sea level can not be used directly when diving at reduced atmospheric pressures. Altitude-corrected standard air decompression tables, oxygen decompression tables, and repetitive diving tables, based on the DCIEM 1983 decompression model, have been developed for the Canadian Forces School of Aeromedical Training (CFSAT) at Edmonton, Alberta. These tables can be used directly since they have been calculated for the elevation of Edmonton. Treatment tables, which are designed for use at sea level, also can not be used directly at altitude. An analysis of treatment tables shows that the standard treatment tables, if dived exactly with air only as the breathing gas, are unsafe for the inside attendant and that oxygen breathing towards the end of the tables is necessary to reduce the risk of decompression sickness.

Nishi, R. Y. (1986). **New Canadian Air Decompression Tables.** *Canadian Diving Journal, Summer,* 22-27.

Abstract The Defence and Civil Institute of Environmental Medicine has recently developed a new set of decompression tables for compressed air diving for use

by the Canadian Forces. The new tables include those for Standard Air, In-water Oxygen Decompression, Surface Decompression with Oxygen, Repetitive Diving, and Corrections for Diving at Altitude. Of interest to the recreational diver are three tables: Short Standard Air, Repetitive Dive Factors and Allowable No-Decompression Limits for Repetitive Dives. These tables are described in detail with instructions for their use. Examples are given, followed by a short exercise on applying the tables.

Nishi, R. Y. (1986). **Major New Tables from DCIEM.** *Pressure, 15*(1), 5-6.

Abstract The Defence and Civil Institute of Environmental Medicine has recently developed a new set of decompression tables for compressed air diving for use by the Canadian Forces. The new tables include those for Standard Air, In-water Oxygen Decompression and Surface Decompression with Oxygen. In addition, tables for Repetitive Diving and Corrections for Diving at Altitude have also been developed. A simplified version of the standard air tables and the repetitive dive tables are described.

Tikuisis, P. (1986). **Modeling the observations of in vivo bubble formation with hydrophobic crevices.** *Undersea Biomed Res, 13*(2), 165-180.

Abstract In vivo hydrophobic crevices from which bubbles emerge upon decompression are hypothesized to account for experimental observations of bubble formation in decompressed shrimp. The conical crevice model can be used to explain the sharp increase in the number of bubbles observed in shrimp for decompression ratios greater than 4:1. In accordance with the observed attenuating effects of pressure pretreatment on bubble formation in shrimp, the model can also be used to explain: (a) the evolution of the gas nuclei to smaller stable sizes during compression; (b) the return of the nuclei to their original stable configurations when the overpressure is removed; and (c) the requirement for greater decompressions to cause emergence of bubbles from the nuclei as the magnitude and period of pressure pretreatment are increased. A new crevice geometry with elliptically shaped walls is introduced which reduces the height of the crevice needed for bubble emergence and relaxes the constraints for the stability of gas nuclei. This new geometry reduces the height of crevices required for the prediction of bubble emergence an order of magnitude when compared to the conical crevice, and satisfies the hydrophobic crevice condition as long as the crevice surface has a contact angle greater than 90°.

Ward, C. A., Tikuisis, P., & Tucker, A. S. (1986). **Bubble evolution in solutions with gas concentrations near the saturation value.** *J. Colloid. Interface Sci., 113*, 388-398.

Abstract Conventional methods for predicting the rate of bubble evolution usually neglect the vapor inside the bubble and assume that as the bubble evolves, the gas concentration in the liquid phase at the bubble boundary is the equilibrium value corresponding to conditions inside the bubble. For liquid-gas solutions with gas concentrations near the saturation value, these approximations are inadequate. Recently a new method has been proposed for predicting the rate of bubble evolution in which the effects of the vapor are included and the finite rate of gas transfer at the bubble boundary is accounted for without the addition of any new fitting parameters. We compare the predictions from this new approach with the results of a novel set of experiments in which two bubbles are intro-

duced simultaneously into a liquid gas solution with initial radii such that one grows and simultaneously the other dissolves. This allows us to establish accurately the initial gas concentration. The calculations of the bubble radius as a function of time from this new technique are found to closely reflect the measurements, whereas the conventional techniques are found to be in contradiction with the measurements.

Weathersby, P. K., Survanshi, S. S., Homer, L. D., Hart, B. L., Nishi, R. Y., Flynn, E. T., & Bradley, M. E. (1986). ***Statistically based decompression tables I. Analysis of standard air dives: 1950-1970.*** (NMRI 85-16). Naval Medical Research Institute, Bethesda, MD.

Abstract A large number of air dives was examined by a new methodology. Several essentially empirical models of decompression risk were considered that predicted the probability of decompression sickness (DCS) for a given pressure exposure to avoid the infinitely sharp threshold parameters that have characterized previous calculation of decompression tables. The candidate models used several distinct formulations of tissue gas exchange kinetics and summed tissue overpressures that are calculated during the dive to estimate decompression risk. The models were compared to decompression outcome data using the statistical principle of maximum likelihood.

Reported decompression trials from American, British, and Canadian Naval laboratories were examined individually and collectively to evaluate the probabilistic models and their parameters. Only two to five parameters were found to be justified by the available data (more than 1,700 individual exposures were considered). Diving data from various sources were only partially compatible; some of the discrepancy may arise from an evolution of diagnostic criteria over several decades. Predictions were made of the outcome for additional reported diving series, and they were only partly successful. The models were then used to estimate decompression risk for current USN air diving with a finding of a wide range of hazard. Specifically, it appears that short dives are quite safe, even to a moderately deep depth, while long exposures are very risky regardless of depth. These findings will be used to produce a set of standard air tables with a uniform and low level of DCS risk. Subsequent work will extend this approach to provide a single model for many forms of diving, thus allowing a new range of operational flexibility.

1987

Eatock, B. C., & Nishi, R. Y. (1987). **Analysis of Doppler ultrasonic data for the evaluation of dive profiles.** In A. A. Bove, A. J. Bachrach, & L. J. Greenbaum Jr (Eds.), *Underwater Physiology IX, Proceedings of the Ninth International Symposium on Underwater and Hyperbaric Physiology.* (pp. 183-195). Bethesda, MD: Undersea and Hyperbaric Medical Society.

Abstract The development of decompression tables or evaluation of dive profiles has been traditionally based on the observation of decompression sickness (DCS). A better method of evaluating dive profiles as a supplement to the traditional method is the use of the Doppler ultrasonic bubble detector to detect venous gas emboli (VGE). It provides far more data than observing the incidence of DCS and it is often possible to use bubble observations to compare the results of two dives, even in the absence of DCS. The meaning of the data is often open to different interpretations because the occurrence of bubbles does not directly lead to observable symptoms of decompression sickness. However, the risk of DCS does appear to be increased for large numbers of VGE and conversely, the risk of

DCS appears to be small when few or no bubbles are detected. The purpose of this paper is to discuss the problems of analyzing bubble data and how to use the data to evaluate decompression profiles. If the association between bubbles and DCS were better established, the criterion for accepting or rejecting profiles could be expressed as a function of bubbles observed. Doppler data are categorical, so parametric statistical techniques (e.g., mean, standard deviation, analysis-of-variance) cannot be used for analysis. Some non-parametric statistical tests for handling categorical data will be recommended and illustrated here with examples from experimental dives. They are more likely to produce significant results than invalid application of parametric tests.

Eatock, B. C., & Sweeney, D. M. C. (1987). ***Digital processing of doppler ultrasonic signals for intravascular bubbles.*** (DCIEM 87-RR-19). Defence and Civil Institute of Environmental Medicine.

Abstract This report describes progress made in the development of a system for the automatic detection of bubbles by digitally processing Doppler ultrasonic signals. The system was developed primarily because of the need for an objective means of counting bubbles in the blood of divers, aviators, or other individuals who have been subjected to a reduction in ambient pressure. The number of bubbles is thought to indicate the stress felt by an individual as a result of the decompression. The characteristics of the signals are described, and the theory underlying the development of the algorithm is developed. The results of tests of the algorithm on various signals are presented. The algorithm is successful at detecting the presence of bubbles when they are moderately frequent, but does not distinguish infrequent bubbles from normal cardiac signals, and fails to distinguish bubbles when they are extremely numerous. To deal with the latter case, pattern matching should be used.

Eaton, D., & Romet, T. (1987). ***Standardized test procedures for evaluations of diving life support equipment using human subjects: A working paper.*** (DCIEM 87-TR-25). Defence and Civil Institute of Environmental Medicine.

Abstract Members of the ABC-35 Information Exchange Program are attempting to establish standard tests for diving life-support equipment evaluations that involve humans. The paper presents a framework for some of the tests. The first topic considered is the characterization of the dive subjects in terms of physical characteristics, cardio-respiratory function, strength, and thermoregulatory response. Secondly, evaluation protocols for testing breathing apparatus and thermal protection devices are discussed. It was recommended that a standard glossary of terms be produced to reduce misinterpretation of research.

Hjelle, J. O., Eatock, B. C., & Nordahl, S. H. (1987). **Doppler monitoring during 3 dives to 360 msw.** In *XIIIth Annual Meeting of the European Undersea Biomedical Society,* (pp. 67-76). Palermo, Italy: EUBS.

Abstract Six divers participated in each of 3 heliox dives to 360 msw at NUTEC, totalling 18 different divers. The decompression rate was 27 msw/24 hours with 6 hour night stops from 360 to 14 msw, followed by a gradually decreasing rate to the surface. The partial pressure of oxygen during decompression was 0.5 bar from 360 msw to 14 msw, later the oxygen percentage was 21. The Doppler ultrasound unit was a multifrequency pulsed system. A 2 MHz transducer was used for monitoring the right side of the heart, and a 5 MHz trans-

ducer for the subclavian veins, the femoral veins and the carotid arteries. The first venous bubbles were found at 345 msw, 10 hours after the decompression started. There was an increase in the number of venous bubbles detected during the decompressions. The highest bubble grades detected either precordially or in the femoral veins were Grade III, in 7 divers at rest and in all divers after movement (Kisman-Masurel Code). In one diver persistent venous bubbles were detected 15 hours post-dive. Doppler signals characteristic for gas phase were found in both carotid arteries of one diver following knee-bending in two afternoon sessions at the depths of 21 msw and I msw without any simultaneous symptoms. At shallow depth, one diver developed intense, but transient knee pains that could be interpreted as DCS. Seven other divers experienced some intermittent discomfort and pains in the lower limbs during the end of decompression.

Nishi, R. Y. (1987). **The DCIEM decompression tables and procedures for air diving**. In I. Nashimoto & E. H. Lanphier (Eds.), *Decompression in Surface-Based Diving, Proceedings of the Thirty-sixth UHMS Workshop, 11-12 Sept. 1986, Tokyo, Japan.* (pp. 80-83). Bethesda, Md.: Undersea and Hyperbaric Medical Society, Inc.

Abstract New decompression tables for compressed air diving have been developed by DCIEM for use by the Canadian Forces. These include tables for standard air dives, dives with in-water oxygen decompression, and dives using surface decompression with oxygen. Repetitive dive procedures and depth corrections for diving at altitude were also developed. Although these tables were developed in 1983, the history of the decompression model underlying the tables goes back over 20 years. The standard air decompression table, in general, is more conservative than the US Navy or Royal Navy standard air tables. The in-water oxygen table uses 100% oxygen at 9 metres of seawater (msw) until the decompression requirements are met. The surface decompression table has been modified from those in general use by keeping the last in-water stop at 9 msw, ascending directly to the surface and returning to 12 msw in a recompression chamber within 7 min, and then breathing oxygen until the decompression requirements are satisfied. Air breaks are taken after each 30-min period on oxygen. All three decompression tables cover the depth range to 72 msw. The bottom times allowed at each depth are defined by a normal air diving limit and an exceptional exposure limit. The normal air diving limit does not extend beyond 54 msw. Validation of the decompression tables was done by testing selected profiles, both in the normal air diving range and in the exceptional exposure range. About 900 man-dives, both dry-resting and wet-working, were conducted using the Doppler ultrasonic bubble detector and clinical symptoms of decompression sickness as criteria for determining the decompression stress and the safety of the model. Repetitive dive procedures were tested with all three decompression procedures. All dive profiles tested were controlled by a real-time on-line decompression computer which took into account the actual time-pressure profile. Hence, the mathematical model was always being tested instead of the printed tables derived from the model. The DCIEM decompression tables have now been officially adopted for use by the Canadian Forces for all air diving operations and are also being used by several commercial diving companies and commercial diving schools.

Romet, T. T., Padbury, E. H., & Grodski, J. J. (1987). ***Diver Heating at Depths to 360 msw.*** (DCIEM 87-RR-07). Defence and Civil Institute of Environmental Medicine.

Abstract Manned diving experiments at simulated depths up to 360 msw were carried out at DCIEM's Diving Research Facility. Data were obtained on respiratory gas heating with both the GSOL helmet and Heliox 18B band mask as well as the thermal protection provided by three hot water suits; NRV II, by Diving Unlimited Intl., U.S.A., FCO by Finn-Christian Olson & Son, Norway and Divematics by Divematics, U.K. Six skin temperature sites (back, arm, chest, thigh, calf and foot) and core temperature (rectal) were continuously monitored and minute averages recorded by a computer controlled data acquisition system. Breath-by-breath measurement of inspired and expired temperatures were obtained by a rapid responding bead thermistor located in the oral-nasal mask. Subjective thermal comfort was assessed using a 13 point scale.

Both the NRV and FCO open circuit design suits maintained core and skin temperatures during exercise and simulated manual work with mean skin temperatures remaining remarkably uniform for both suits during the various activities performed. The FCO suit ensemble, however, had difficulties in maintaining thermal comfort in the hands and feet. Both suits integrated well with the shroud/respiratory gas heating system. A hot water flow rate of 18 1/min to the suit with 6.6 1/min of flow diverted to the shroud was sufficient to maintain the temperature and comfort of both the body and inspired gas within acceptable limits.

The Divematics heating system was found to be more than adequate with respect to the quantity of heat delivered, even at the lowest operating temperatures of the heating unit and with 60% of the flow bypassing the suit. However, the trunk and thighs were too hot with the present flow and distribution of hot water and the extremities, especially the hands were too cold. Additional problems with water leakage and the excessive buoyancy of the suit were also encountered. It is suggested that the system be modified to provide lower delivery temperatures to the suit and the clothing ensemble be re-configured.

1988

Eaton, D. J. (1988). ***Canadian Underwater Mine Apparatus: Manned Evaluation of the First Prototype.*** (DCIEM 88-TR-31). Defence and Civil Institute of Environmental Medicine.

Abstract Two series of manned evaluations using a prototype version of the Canadian Underwater Mine Apparatus (CUMA) were completed in the wet chamber of the Defence and Civil Institute of Environmental Medicine Diving Research Facility. The CUMA is a self-contained rebreather apparatus employing a gas supply system that mixes pure oxygen with a diluent gas. The resultant gas mixture supplied to the counterlung has a constant oxygen partial pressure over the depth range of the apparatus. Operationally, the diluents used are nitrogen for depths up to 55 metres of seawater (msw) and helium to 80 msw. In the first evaluation the apparatus was tested using nitrogen diluent at 15, 20, 36, 45 and 60 msw during a total of 20 dives. Helium diluent was used during the eleven dives of the second series at depths of 45, 60, 80 , and 90 msw. The same four Canadian Forces Clearance Divers participated as subjects in both evaluations. During each dive the subject exercised on a bicycle ergometer. In the nitrogen series two work protocols were used. The first involved continuous work at an ergometer setting of 50 watts (W) from the time of compression to the end of the bottom-time. The second was an incremental protocol to maximum energy expenditure with work commencing once on the bottom. Only the continuous work protocol was used during the helium diluent series. Data collected included inspired oxygen and carbon dioxide partial pressures. Results from the evaluations were very promising. The mechanical

problems were relatively minor, but the blockage of the oxygen flow control valve during one of the nitrogen series dives caused the inspired oxygen level to drop below the design limit of 0.50 atmospheres absolute (ATA) to 0.30 ATA. This further emphasized the need for a functional diagnostic system and bail-out that would inform the diver of gas-mixer malfunctions and permit safe exit from the water. During the evaluations a number of operational problems became evident. Helium decompression was the most apparent. However, the general conclusions were that the technique used for mixing the gas worked as predicted. It was recommended that development of the apparatus continue and that parallel work be conducted to develop operational diving techniques and support.

Eaton, D. J. (1988) ***Estimating Motor Performance Decrements Using Ratings of Perceived Discomfort.*** M.Sc., School of Human Biology, University of Guelph, Guelph, Ontario.

Abstract This thesis investigated the existence of a relationship between perceived discomfort and manual control task performance during fatiguing contractions of postural muscles. The relationship would establish the basis of a workplace questionnaire for estimating performance decrements due to postural constraint. Fourteen trained, male subjects performed an adaptive pursuit tracking task with the right hand with the right shoulder flexed 90° from vertical and the elbow fully extended. The task was performed while seated and continued until voluntary exhaustion. Fifteen minutes later the task was repeated to exhaustion. The tracking system adapted the frequency of the single sinusoid driving the target in inverse proportion to the absolute error between the cursor and target displayed on an oscilloscope screen. Performance scores were the frequency of the target motion recorded at 5 second intervals. Discomfort was measured using an eleven point ratings of perceived discomfort scale developed for the experiment. Further subjective scores were obtained using a modified version of the McGill Pain Questionnaire. The questionnaire results showed strong trends towards specific discomfort related adjectives which would be useful for workplace questionnaire development. Separate linear regressions of discomfort and frequency against time-on-task were significant; however, correlations of frequency against time-on-task were low. A variety of filtering and regression methods were used, with some success, to improve the frequency-time relationship. Recommendations were made for improvements to future experiments using the adaptive tracking task. The regression of frequency against discomfort was strong enough to show operationally significant decreases in performance with increased discomfort ratings.

Fairburn, S. M., Romet, T. T., & Eaton, D. J. (1988). ***On-land validation of the Underwater Metabolic Assessment System (UMAS).*** (DCIEM 88-RR-47). Defence and Civil Institute of Environmental Medicine.

Abstract The recent increase in underwater research has produced an accompanying need for methods to assess energy and ventilatory requirements of diving activities. In response, The Defence and Civil Institute of Environmental Medicine (DCIEM) designed and built the Underwater Metabolic Assessment System (UMAS). It consisted of a low-resistance, open-circuit, bag-in-box breathing apparatus and its main feature was its compact size allowing it to be worn on a diver's back in water or in air. Moreover, it was simple, adjustable, and allowed control of respiratory hydrostatic loading. The results of a study to validate its on-land (dry) performance by comparing the results to the per-

formance of a commercially available standard metabolic cart (Jaeger Ergo-Oxyscreen) are described. Nine male volunteers, aged 26-36, participated in these steady state and maximal exercise trials. Expiratory tidal volume and expired fractions of carbon dioxide and oxygen were measured. Values for oxygen consumption, carbon dioxide production and ventilation were then calculated for both the UMAS and the metabolic cart. In all cases, the relationships between the two systems were highly correlated and significant. The UMAS proved to be a reliable and accurate system for on-land measurement of metabolic and respiratory parameters.

Gilmour, K. M., Eaton, D. J., & Romet, T. T. (1988). ***Measurement of oxygen consumption using the Canadian Clearance Diving Apparatus (CCDA).*** (DCIEM 88-RR-46). Defence and Civil Institute of Environmental Medicine.

Abstract The Canadian Clearance Diving Apparatus (CCDA) was modified to serve as a 100% oxygen rebreathing system for the measurement of oxygen consumption ($\dot{V}O_2$) in water. Four physically active male subjects each performed three exercise tests on an electromagnetically-braked bicycle ergometer: in shorts on dry land; in shorts while submerged; and in wet suits while submerged. Mean $\dot{V}O_2$ for dry exercise was significantly less than mean $\dot{V}O_2$ for either wet condition. The mean $\dot{V}O_2$ values for the two wet conditions were not significantly different, but no subject was able to complete the work protocol in wet suits. It was suggested that the constrictive nature of the wet suit restricted blood flow to the muscles, thereby reducing the removal of metabolic waste products and the supply of oxygen, leading to an increase in muscle fatigue. Comparison of the results with standard values and results obtained using the Low Resistance Breathing Apparatus (LRBA) indicated that the CCDA is a viable system for the measurement of $\dot{V}O_2$ in water.

Marshall, S., & Eaton, D. J. (1988). ***Development of a Replacement Diving Set for the Clearance Diving Breathing Apparatus (U).*** (DCIEM 88-TR-24 (Confidential)). Defence and Civil Institute of Environmental Medicine.

Abstract This report describes the development of a replacement for the Clearance Diving Breathing Apparatus (CDBA) by the Experimental Diving Unit at the Defence and Civil Institute of Environmental Medicine and Fullerton-Sherwood Engineering Ltd. from its start in October 1984 to the start of production in January 1988. The report covers the various tests and evaluations carried out, the results of these and recommendations for the future. The new set, called the Canadian Clearance Diving Apparatus (CCDA), has proved to be an excellent MCM diving apparatus compared to the present equipment used and it has attracted interest from several other Navies around the world.

Nishi, R. Y., & Hobson, B. A. (1988). **The DCIEM/Canadian Forces Air Decompression Tables.** In S. B. M. Langley (Eds.), *Proceedings of the Third Annual Scientific Symposium: Diving for Science 1986, Assessing the Environment.* (pp. 79-86). Victoria B.C.: Canadian Association of Underwater Science.

Abstract The DCIEM decompression tables were developed in 1983 as a replacement for the US Navy Standard Air Tables for Canadian Forces use. A brief history of the development is described, starting with the research started in 1962 by Kidd and Stubbs which led to a highly successful decompression computer. The new

DCIEM/CF decompression tables have been based on the Kidd-Stubbs model. The objective was to correct some of the deficiencies and anomalies in the model to achieve a safer set of tables. The new decompression tables are more conservative than the US Navy and Royal Navy standard air tables. Of interest to the scientific diver are four tables: Short Standard Air, Depth Corrections for Diving at Altitude, Repetitive Dive Factors, and Allowable No-Decompression Limits for Repetitive Dives. These four tables are described.

Tikuisis, P., Nishi, R. Y., & Weathersby, P. K. (1988). **Use of the maximum likelihood method in the analysis of chamber air dives.** *Undersea Biomed Res, 15*(4), 301-313.

Abstract The method of maximum likelihood was used to evaluate the risk of decompression sickness (DCS) for selected chamber air dives. The parameters of two mathematical models for predicting DCS were optimized until the best agreement (as measured by maximum likelihood) corresponding to the observed DCS incidents from a series of dives was attained. The decompression data used consisted of 800 man-dives with 21 incidents of DCS and 6 occurrences of marginal symptoms. The first, model investigated was based on a nonlinear gas exchange in a series arrangement of four compartments. The second model was based on a monoexponential gas exchange in a parallel arrangement of two compartments. The overall statistical success in describing the 800 man-dives was quite similar for the two models. Predictions of safety for dives not part of the original data differed for the models due to differences in gas kinetics. For short, no-decompression dives, the series arrangement of compartments predicted a lower incidence of DCS. These predictions were more consistent with the outcome of subsequent testing than were predictions of the parallel compartment model. Predictions of the series arrangement model were also similar to those of a single-compartment, two-exponential model that was evaluated with over 1700 man-dives by the U.S. Navy.

1989

Eaton, D. J. (1989). ***Canadian Underwater Mine Apparatus: Unmanned Performance Validation of the Second Prototype Second-Stage Regulator.*** (DCIEM 89-TR-44). Defence and Civil Institute of Environmental Medicine.

Abstract The Canadian Underwater Mine Apparatus (CUMA) is a rebreather type apparatus employing a self-contained gas supply system that mixes pure oxygen with a diluent gas. The resultant gas mixture supplied to the counterlung has a constant oxygen partial pressure over the depth range of the apparatus. Operationally, the diluents used are nitrogen for depths up to 55 metres of seawater (msw) and helium to 80 msw. After the evaluation of the first prototype of the CUMA, it was recommended that the second stage regulator in diluent circuit be re-engineered to increase its compatibility with helium and saltwater before open water trials to 80 msw were attempted. The contractor, Fullerton, Sherwood Engineering Limited, produced a new regulator that the Experimental Diving Unit of the Defence and Civil Institute of Environmental Medicine evaluated prior to further manned dives with the CUMA prototype. Apparatus were set up to reproduce the diluent circuit and allow simulation of diving the circuit. Tests of the regulator were repeated three times for each combination of diluent (helium or nitrogen), high pressure supply (500 to 1000 pounds per square inch, gauge (psig) or 2000 to 3000 psig), first stage regulator output setting (140, 155 and 170 psig) and depth (pressures equivalent to 0 to 9 Bar gauge). The results showed a

highly linear and repeatable function of the second stage regulator in relation to depth. Additionally, no gas leaks were found in the regulator. It was recommended that the new second stage regulator would be suitable for continued manned evaluations of the CUMA.

Eaton, D. J. (1989). **Future Developments in Unmanned Underwater Breathing Apparatus Testing.** In C. E. G. Lundgren & D. E. Warkander (Eds.), *Physiological and Human Engineering Aspects of Underwater Breathing Apparatus, The Fortieth UHMS Workshop.* (pp. 179-192). Bethesda, MD: Undersea and Hyperbaric Medical Society, Inc.

Abstract Unmanned testing of underwater breathing apparatus has evolved over a number of years. The state-of-the-art involves using breathing machines that reproduce human respiratory demands to determine external work of breathing, peak mouth pressures, and inspired gas quality. Evaluation laboratories use standard measurement procedures and a number of breathing apparatus performance criteria. However, the possibilities for improving techniques and performance criteria have not been exhausted. By increasing our knowledge of human respiratory limitations the validity of breathing machine test results could improve. Consequently, by relating unmanned test results directly to physiological limitations, the life support capacity of a breathing apparatus could be assessed in unmanned trials, while manned trials could concentrate on more subtle human factors such as buoyancy and mobility. Additionally, new techniques, similar to traditional systems analysis methods, could provide engineering information for equipment design and mathematical modelling of breathing apparatus performance.

Hamilton, K., Fowler, B., Landolt, J., & Porlier, G. (1989). **Nitrogen narcosis and ethyl alcohol increase the gain of the vestibular ocular reflex.** *Undersea Biomed. Res., 16*(2), 129-137.

Abstract The effects of air, helium-oxygen (6.4 ATA) and ethyl alcohol (40% by volume at a dose of 1.5 ml/kg body weight) were examined on the gain, number of beats, and phase lag of the vestibular ocular reflex (VOR) by means of electronystagmography (n = 7). It was found that hyperbaric air and alcohol, both alone and in combination, produced approximately the same increase in the velocity of the slow phase component of the nystagmus, thereby elevating the gain of the system to unity. Hyperbaric helium-oxygen did not influence the gain. These findings suggest that nitrogen narcosis differentially impairs the system controlling the VOR. It is proposed that this impairment may help to explain the disorientation sometimes associated with nitrogen narcosis.

Hamilton, K., Fowler, B., & Porlier, G. (1989). **The effects of hyperbaric air in combination with ethyl alcohol and dextroamphetamine on serial choice-reaction time.** *Ergonomics, 32*(4), 409-422.

Abstract The effects of ethyl alcohol (1.5 ml/kg body weight) and dextroamphetamine (15 mg) on nitrogen narcosis were investigated In two experiments using a 2-, 3- and 4-choice serial reaction time (RT) task with accuracy held constant. Narcosis was induced with air at 6.4 atmospheres absolute (ATA) and a heliox mixture was used as a control. Heliox at 6.4 ATA did not affect RT. Alcohol alone and air at 6.4 ATA increased the intercept of the Hick-Hyman function whereas amphetamine alone decreased it. The increased intercept with air at 6.4 ATA was exacerbated additively by alcohol and ameliorated antagonistically by amphetamine. It is concluded

that these data are consistent with the slowed processing model which proposes that the effects of narcosis on performance are due to a decrease in arousal in conjunction with secondary changes in task strategy.

Hobson, B. A. (1989). **Development and validation considerations in decompression table validation**. In H. R. Schreiner & R. W. Hamilton (Eds.), *The 37th Undersea and Hyperbaric Medical Society Workshop, Validation of Decompression Tables.* (pp. 25-31). Bethesda, MD: Undersea and Hyperbaric Medical Society.

Abstract In April of 1985, the Canadian Armed Forces accepted into service a set of new Air Decompression Tables based on the DCIEM 1983 Decompression Model. The major factors that influenced the development and validation of that model will be described. During the development phase, these included the identification of the scientific, medical and operational personnel forming the development and validation program, the approach to be taken (scientific vs. operational) in order to achieve the objectives of the program, identification or development of a candidate decompression model, extensive computer simulation, analysis and comparison with other accepted decompression models, and definition of procedures to meet the concerns and requirements of the operators. During the validation phase, these included the selection of profiles to be tested, the number of dives, data collection and analysis considerations, subject selection and control, chamber considerations (including approximations to field conditions), and development of emergency procedures.

Nishi, R. Y. (1989). **Dive Computer Experience in Canada.** In M. A. Lang & R. W. Hamilton (Eds.), *Proceedings of Dive Computer Workshop.* (pp. 69-79). American Academy of Underwater Sciences.

Abstract Dive computer research and development in Canada first started in 1962 at the Canadian Forces Medical Services Institute of Aviation Medicine. The Kidd-Stubbs pneumatic analogue dive computer was extensively tested with approximately 5000 man-dives involving single dives, repetitive dives and random depth dives. A commercial version of this computer was developed by SPAR Aerospace Products Ltd. When microprocessors became available, a series of digital, microprocessor-controlled dive computers was developed for the Defence and Civil Institute of Environmental Medicine, including a dive calculator, surface/hyperbaric chamber monitor and a diver-carried computer. This research and development resulted in the commercially available Cyberdiver diver-carried dive computer. In addition to the extensive monitoring of experimental, training and operational dives at DCIEM, dive computers have been used for developing dive tables and dive procedures.

Nishi, R. Y. (1989). **Theoretical Considerations for Calculating Flying After Diving.** In P. J. Sheffield (Eds.), *Proceedings of the Thirty-ninth UHMS Workshop, Flying After Diving.* (pp. 122-134). Bethesda, MD: Undersea and Hyperbaric Medical Society.

Abstract The prediction of flying after diving times based on decompression models used to generate dive tables requires the consideration of other factors which may not be as important when calculating dive tables. Most commonly used decompression tables and dive computers are based on models that have an ascent crite-

rion in which the allowable nitrogen value (M-value) is linearly related to the ascent depth. The M-value cannot be extrapolated to altitude and must be changed for calculating flying after diving times. Compartments with longer half-times must also be considered since flying after diving can be considered to be analogous to calculating the decompression requirements following excursion diving during a saturation dive. In addition, no clear-cut distinctions can be made between no-decompression dives and those requiring decompression stops. These are illustrated by examples based on a number of Haldanian decompression models.

Nishi, R. Y., & Eatock, B. C. (1989). **The Role of Ultrasonic Bubble Detection in Table Validation.** In H. R. Schreiner & R. W. Hamilton (Eds.), *The 37th Undersea and Hyperbaric Medical Society Workshop, Validation of Decompression Tables.* (pp. 133 -137). Bethesda, MD: Undersea and Hyperbaric Medical Society.

Abstract The validation of decompression tables has been traditionally based on the absence of clinical symptoms of decompression sickness (DCS) in a set number of dives. From a statistical point of view, proving the safety of dives using this method with any degree of confidence would require many more dives than are normally feasible. Ultrasonic monitoring of bubbles in divers provides a method to assist in the evaluation of the safety or risk of dive profiles. This presentation reviews briefly ultrasonic methods of bubble detection and discusses the considerations required for table validation. The Doppler ultrasonic bubble detector is the most useful for table validation since it can give a measure of the decompression stress of a dive. Experience has shown that dives which produce many bubbles in the majority of subjects have a higher risk of DCS than dives which produce few or no bubbles in the subjects. Thus this provides a basis for assessing the severity of the decompression stress. Based on DCIEM's experience in using the Doppler ultrasonic bubble detector for evaluating dive tables, standardized procedures for bubble detection are recommended.

Nishi, R. Y., & Eaton, D. J. (1989). **Current Developments in Canada Regarding Nitrox and Semi-Closed Circuit Diving Systems.** In R. W. Hamilton, D. J. Crosson, & A. W. Hulbert (Ed.), *Harbor Branch Workshop on Enriched Air Nitrox Diving,* National Undersea Research Program Research Report 89-1, (pp. 115-122). Washington, D.C.: National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

Abstract The Canadian Clearance Diving Apparatus is a semi-closed circuit breathing apparatus in use by the Canadian Forces. This apparatus and its commercial version are designed for use to 55 metres of seawater using premixed gases. The decompression requirements for semi-closed circuit systems are generally determined from the Standard Air Tables using the equivalent air depth, and these procedures have been shown to be reliable. There are advantages and disadvantages of developing specific decompression tables based on the actual oxygen content in the counterlung. Such tables can lead to shorter decompression times and increased no-decompression capability, but they lead also to increased complexity and some uncertainty because of changing oxygen levels. Other options exist for use of the CCDA in other operational modes such as umbilical supplied.

1990

Eaton, D. J. (1990). ***Water Vapour Content and its Effect on CABA.*** (DCIEM 90-R-29). Defence and Civil Institute of Environmental Medicine.

Abstract During the winter months the Canadian Forces (CF) have experienced problems with high water content levels in divers' compressed breathing gases. One problem investigated was the validity of the standard used to specify water content levels. The standard suggests that water is a contaminant in the compressed gas because it might cause freezing of the breathing apparatus regulators. Present thinking disagrees with this suggestion; consequently, an experiment was performed in which 4 diving regulators used by the Canadian Forces were tested in -1.0 to 0.0°C salt water. Two conditions were tested. The first used compressed air saturated with moisture at 3000 psig. The second used air at 3000 psig with no more than 5 millilitres per cubic metre (mL/m^3) by volume water content. The protocol created freeze-up conditions by activating the second stage purge button for 5 s, stopping for 5 s and then repeating this cycle until 1500 psig remained in the supply cylinder. Only one of the regulators did not free-flow in either condition; however, no free-flows were attributed to ice. Instead, material performance under cold conditions was blamed. Therefore, it was recommended that the CF standard be revised to remove water vapour as a cause of compressed air breathing apparatus regulator freeze-up. The recommended maximum level for moisture content in compressed air breathing apparatus air supplies was 50 mL/m^3 by volume based on the standards used by other NATO forces. Calculations revealed that at this level the gas would contain little water to cause corrosion; however, it was considered prudent to recommend an analysis of the possibility of corrosion in compressed gas distribution and storage facilities.

Eckenhoff, R. G., Olstad, C. S., & Carrod, G. (1990). **Human dose-response relationship for decompression and endogenous bubble formation.** *J. Appl. Physiol., 69*(3), 914-918.

Abstract The dose-response relationship for decompression magnitude and venous gas emboli (VGE) formation in humans was examined. Pressure exposures of 138, 150, and 164 kPa (12, 16, and 20.5 ft of seawater gauge pressure) were conducted in an underwater habitat for 48 h. The 111 human male volunteer subjects then ascended directly to the surface in <5 min and were monitored for VGE with a continuous-wave Doppler ultrasound device over the precordium or the subclavian veins at regular intervals for a 24-h period. No signs or symptoms consistent with decompression sickness occurred. However, a large incidence of VGE detection was noted. These data were combined with those from our previously reported experiments at higher pressures, and the data were fit to a Hill dose-response equation with nonlinear leastsquares or maximum likelihood routines. Highly significant fits of precordial VGE incidences were obtained with the Hill equation (saturation depth pressure at which there is a 50% probability of detectable VGE [$D_{(VGE)50}$] = 150 ± 1.2 kPa). Subclavian monitoring increased the sensitivity of VGE detection and resulted in a leftward shift [$D_{(VGE)50}$ = 135 ± 2 kPa] of the best-fit curve. We conclude that the reduction in pressure necessary to produce bubbles in humans is much less than was previously thought; 50% of humans can be expected to generate endogenous bubbles after decompression from a steady-state pressure exposure of only 135 kPa (11 ft of seawater). This may have significant implications for decompression schedule formulation and for altitude exposures that are cur-

rently considered benign. These results also imply that endogenous bubbles arise from preexisting gas collections.

Nishi, R. Y. (1990). **Doppler Evaluation of Decompression Tables.** In Y. C. Lin & K. K. Shida (Eds.), *Man in the Sea, Volume I.* (pp. 297-316). San Pedro, CA: The Best Publishing Co.

Abstract The Doppler ultrasonic bubble detector is a valuable tool for the evaluation of decompression tables and profiles. The primary location for monitoring bubbles is the precordial region. The signal received from this location is analyzed according to some bubble grading and classification scheme such as the Kisman-Masurel method or the Spencer method. A high level of bubble activity observed in the circulatory system, although not necessarily related to decompression sickness, can be used as an indicator of decompression stress. Experience has shown that individuals who incur decompression sickness generally have high bubble scores and that dives which produce many bubbles in most of the subjects are not desirable from a decompression safety standpoint. The application of the Doppler ultrasonic bubble detector differs depending on the type of decompression profile being monitored. For evaluating decompression tables for non-saturation dives, the Doppler is primarily useful as a post-dive analysis tool. It is not too useful for controlling the rate of decompression of such dives since bubbles quite often do not become detectable until after the surface is reached. As bubbles can persist for several hours after the dive, it is important that subjects be monitored periodically for at least two hours. On the other hand, for saturation dives or for deep, long non-saturation dives requiring substantial decompression, the Doppler monitoring can be done while at pressure during decompression. If an excessively high level of bubble activity is observed at some stage in the decompression, then corrective action can be taken, either by changing the decompression profile or by increasing the partial pressure of oxygen. Continuing the decompression with high bubble activity can lead to potential problems with decompression sickness.

Tikuisis, P., Gault, K., & Carrod, G. (1990). **Maximum likelihood analysis of bubble incidence for mixed gas diving.** *Undersea Biomed Res, 17*(2), 159-169.

Abstract The method of maximum likelihood has been applied to predict the incidence of bubbling in divers for both air and helium diving. Data were obtained from 108 air man-dives and 622 helium man-dives conducted experimentally in a hyperbaric chamber. Divers were monitored for bubbles using Doppler ultrasonics during the period from surfacing until approximately 2 h after surfacing. Bubble grades were recorded according to the K-M code, and the maximum value in the precordial region for each diver was used in the likelihood analysis. Prediction models were based on monoexponential gas kinetics using one and two parallel-compartment configurations. The model parameters were of three types: gas kinetics, gas potency, and compartment gain. When the potency of the gases was not distinguished, the risk criterion used was inherently based on the gas supersaturation ratio, otherwise it was based on the potential bubble volume. The two-compartment model gave a significantly better prediction than the one-compartment model only if the kinetics of nitrogen and helium were distinguished. A further significant improvement with the two-compartment model was obtained when the potency of the two gases was distinguished, thereby making the potential bubble volume criterion a better choice than the gas pressure criterion. The results suggest that when the method of maximum likelihood is applied for the prediction of

the incidence of bubbling, more than one compartment should be used and if more than one is used consideration should be given to distinguishing the potencies of the inert gases.

Tikuisis, P., Nishi, R. Y., Mark, H. L., & Weathersby, P. K. (1990). ***Comparison of Decompression Procedures for HeO2 Dives using the Method of Maximum Likelihood.*** (DCIEM 90-RR-01). Defence and Civil Institute of Environmental Medicine.

Abstract The method of maximum likelihood was used to predict the incidence of decompression sickness (DCS) for two different decompression procedures. These were based on the new DCIEM/CF HeO_2 and the US Navy Surface-Supplied Helium-Oxygen Partial Pressure decompression tables. The dive profiles analyzed consisted of 44 different dives in the depth range from 37 to 99 msw and bottom times from 10 to 120 min. These dives represented exposures within or at the CF normal operational limits and at or beyond the CF exceptional exposure limits. The prediction model consists of mono-exponential gas kinetics with independent time constants for helium and nitrogen, and a DCS risk function based on the inert gas supersaturation. Data from which the model parameters were determined were obtained from a total of 1949 chamber man-dives on air (1041) and on HeO_2 (908). No significant difference in the predicted incidence of DCS was found between the two different decompression procedures. However, the predicted incidence of DCS was frequently lower for dives within the normal operational limits using the DCIEM vs. US Navy decompression procedures. Arguments in favour of the DCIEM decompression procedures other than that suggested by the consistency noted above include procedural simplicity, the use of O_2 at a lower pressure which reduces the risk of O_2 toxicity, and the switch to air during decompression which improves communication and reduces cost.

Weathersby, P. K., Survanshi, S. S., & Nishi, R. Y. (1990). **Relative Decompression Risk of Dry and Wet Chamber Air Dives.** *Undersea Biomed Res, 17*(4), 333-352.

Abstract The difference in risk of decompression sickness (DCS) between dry chamber subjects and wet, working divers is unknown and a direct test of the difference would be large and expensive. We used probabilistic models and maximum likelihood estimation to examine 797 dry (and generally resting and comfortable) and 244 wet (and generally working and cold) chamber dives from the Defence and Civil Institute of Environmental Medicine, supplemented with 483 wet (working, cold) dives from the Navy Experimental Diving Unit. Several analyses considered whether dry and wet data were distinguishable using several models, whether models obtained from one set of exposure conditions would correctly predict the occurrence of DCS in the other condition, and whether a single wet-dry risk difference parameter was different from zero. Although the two conditions may not produce identical risks, immersion appears to change relative risk of DCS by less than 30% and certainly involves less than a doubling of DCS risk. Uncontrolled differences in exercise and temperature stresses unavoidably complicate interpretation. Several methods are presented to extrapolate results from dry-test subjects in decompression trials to expected at-sea performance.

1991

Nishi, R. Y. (1991). **The CANDID diving data base.** In W. Sterk & R. W. Hamilton (Eds.), *European Undersea Biomedical Society Workshop: Operational Dive and Decompression Data: Collection and Analysis.* (pp. 21-30). European Undersea Biomedical Society.

Abstract CANDID (CANadian DIving Data) is a diving and decompression data base containing a detailed record of all dives done in the DCIEM diving program since 1964. This presently consists of approximately 5500 different dive exposures involving about 16000 man-dives and 1700 subjects. These include experimental dives for decompression research, physiological, respiratory, and psychological testing, familiarization, training, and equipment testing. Almost all of the dives have accurate time-depth profile information for the entire dive. CANDID is a relational data base using the INGRES relational data base management system. There are 11 relational tables, six for data entry and five lookup tables, with 30 fields. Data entry and retrieval are conducted by means of a series of convenient menu screens. CANDID has been used extensively for a number of studies, in particular for the development of new air and mixed-gas decompression tables and for the development of probabilistic decompression models using the principle of maximum likelihood. Although CANDID, as presently structured, has been designed primarily as a decompression research data base for chamber dives, it can be used as a general dive data base and can be easily extended into an operational diving data base.

Sawatzky, K. D., & Nishi, R. Y. (1991). **Assessment of inter-rater agreement on the grading of intravascular bubble signals.** *Undersea Biomed Res, 18*(5-6), 373-396.

Abstract Transcutaneous Doppler ultrasonic bubble detectors are widely used in decompression research. However, interpretation of the complex acoustic signals from the bubble detectors involves a degree of subjectivity and the comparability of grades assigned by different raters must be assessed. Hypothetical data were used to determine an appropriate method for evaluating the comparability of Doppler raters and to illustrate the limitations of many nonparametric statistics. Two sets of real data were then used to evaluate this procedure, the first from a training exercise carried out by Kisman and Masurel (1978, unpublished) and the second from a test tape that was independently scored by five DCIEM Doppler technicians. The results were analysed by a two stage approach. First, they were entered into contingency tables and checked for large disagreements, a tendency for one rater to grade higher than the other, and the degree of variability. Second, the results were analysed with the nonparametric weighted kappa statistic. These studies have led to a practical, efficient method for the evaluation of Doppler raters.

Tikuisis, P., Ward, C. A., Weathersby, P. K., & Nishi, R. Y. (1991). **An expanded use of maximum likelihood.** In W. Sterk & R. W. Hamilton (Eds.), *European Undersea Biomedical Society Workshop: Operational Dive and Decompression Data: Collection and Analysis.* (pp. 128-132). European Undersea Biomedical Society.

Abstract The purpose of this study was to demonstrate the implementation and analysis of additional risk factors for the prediction of DCS using the method of

maximum likelihood. These factors can be an attempt to introduce differences between individuals such as complement activation. This study has demonstrated that the additional factor using a relatively small data set can be coupled to an existing probabilistic model. It is emphasized, however, that the development of the existing model required a data set of at least two orders of magnitude higher than the subset involving the individual risk factor. Although many options are available for coupling the additional factor, only one was explored (i.e. multiplicative with a hyperbolic function). Further studies are required to optimize the coupling. If successful, it is conceivable that decompression tables for a specific individual may become possible.

Tikuisis, P., Weathersby, P. K., & Nishi, R. Y. (1991). **Maximum Likelihood Analysis of Air and HeO2 dives.** *Aviat. Space Environ. Med., 62,* 425-431.

Abstract The method of maximum likelihood analysis was applied to data consisting of 1,949 man-dives, of which 1,041 were on air and 908 were on HeO_2 mixtures. These dives represented a wide range of bottom time and depth combinations, and had an overall incidence of decompression sickness (DCS) of 4.64%. Several models, based on single exponential gas uptake in either one or two compartments, were tested for predicting the incidence of DCS. The criterion for defining the risk of DCS was based on the concept of potential gas volume (i.e., the volume of a bubble that could form and be in equilibrium with the remaining gas dissolved in solution). This criterion takes into account the solubilities of the gases in solution, but can be adjusted to account only for the partial pressures of the gases. The best model for the prediction of DCS was found for two compartments where the kinetics (time constants) and not the gas solubilities of nitrogen and helium were distinguished from each other. Results using the best prediction model with the present data suggests the following: 1) most of the risk of DCS occurs after surfacing; 2) most of the risk occurs In the "slow" compartment (approximately 420 min time constant); and 3) nitrogen contributes about twice as much as helium to the risk of DCS for HeO_2 dives.

1992

Chapple, J. C. B., & Eaton, D. J. (1992). ***Development of the Canadian Underwater Mine Apparatus and the CUMA Mine Countermeasures Dive System.*** (DCIEM 92-06). Defence and Civil Institute of Environmental Medicine.

Abstract The Canadian Underwater Mine Apparatus (CUMA: commercial name SIVA+) is a semi-closed circuit constant partial pressure oxygen/helium rebreather diving set and provides a major new Mine Countermeasures (MCM) diving capability. CUMA was developed by the Experimental Diving Unit at the Defence and Civil Institute of Environmental Medicine in conjunction with Fullerton Sherwood Engineering Limited in response to a Department of National Defence requirement.

The report describes the development of the CUMA and the associated development, by DCIEM (EDU), of the CUMA MCM Dive System. The period is from September 1985 to January 1992. Intended as a historical reference document, the report is divided into 4 sections which cover:

1. Technical description of the CUMA.
2. In chronological order, the various experiments and evaluations carried out to develop the breathing apparatus.
3. Development of the associated MCM dive system components as well as the decompression considerations.

4. Future developments, including a lightweight surface-supplied version and overseas sales.

In summary, the project to extend the capability of the CCDA has been a success and is a prime example of a military equipment development and procurement project completed on time and within budget forecasts. In-large part this has been accomplished through the close cooperation maintained between the research and development establishment (DCIEM (EDU)), the NDHQ office of primary interest (DMEE) and the civilian contractor (FSEL).

Numerous unmanned and manned trials were completed and the data used to further develop, modify and refine the eventual CUMA design. Modifications required during the project were incorporated without major problems. The result is an apparatus that is in service with the CF and a range of MCM diving accessories and procedures that together comprise the CUMA MCM Dive System. Work continues at DCIEM to develop a new CUMA HeO2 decompression table under the ABCA-10 agreement.

The philosophy adopted at the outset of the project was to design a physiologically suitable breathing loop and to combine this with a gas supply system appropriate to the diving application. Thereby divers would remain familiar with the common equipment interface in a variety of apparatus configurations. This approach has been proved valid and the development work on CCDA/SIVA 55 and CUMA/SIVA+ has opened up possibilities for further modifications and derivatives. This includes the lightweight surface-supplied (LWSS) version with an increased depth and gas endurance rating.

In operational terms, the CUMA/SIVA+ represents a quantum leap in manned seabed intervention capability. Self-contained MCM diving can now be conducted at depths up to 81 msw (270 fsw) where, in the past, 54 msw (180 fsw) was the technical and physiological limit. The CUMA meets the modern requirements of MCM diving and provides each user with a reliable, safe and diver-friendly set.

DeJong, J., & Cox, G. (1992). **Current thermal protection for the Canadian Forces diver.** In R. Y. Nishi (Ed.), *Proceedings of the DCIEM Diver Thermal Protection Workshop, 31 Jan - 2 Feb 1989,* DCIEM No. 92-10, (pp. 3-5). North York, Ontario: Defence and Civil Institute of Environmental Medicine.

Abstract A diver in the Canadian Forces (CF) requires specialized protection to handle Canada's rugged environmental conditions. These conditions vary between the east and west coast. The east coast experiences colder water conditions through out the year with only a slight warming trend in late summer, early fall. The coldest time on the west coast is in late December and January. The water and surface temperatures in the west seldom get as low as the east coast and so there are definite differences in the type of diving suit and thermal protection preferred. In the CF we rely on both passive and active suit heating. The wet and dry suits rely on the body to heat up the layer of water or air that is between diver and the suit. In the hot water suits, hot water is pumped down to the divers to heat the area between the diver and the suit.

McDougall, S. (1992). **Thermal problems encountered with 75 msw diving.** In R. Y. Nishi (Ed.), *Proceedings of the DCIEM Diver Thermal Protection Workshop, 31 Jan - 2 Feb 1989.*, DCIEM No. 92-10, (pp. 7-10). North York, Ontario: Defence and Civil Institute of Environmental Medicine.

Abstract 75 metre Oxyhelium Diving is carried out by Units of the Royal Navy Fleet Diving Group. The 75 m diving system

is intended for maximum flexibility, including deployment from small craft down to rubber-boat size. Some of the tasks assigned to this system require moderately long bottom times, and thermal stress is imposed on divers in the cold waters surrounding the UK. Thermal protection is passive in nature only, due to the flexibility required of the system. A review of passive thermal protection equipment currently in use with the RN 75 m diving system is presented, along with a discussion of tasks, in-water exposure times and water/weather conditions normally encountered in UK waters. An illustration of space constraints is also presented, to show the limitations imposed. Some projections of future direction in this area are also discussed.

Nishi, R. Y. (Ed.). (1992). ***Proceedings of the DCIEM Diver Thermal Protection Workshop, 31 Jan - 2 Feb 1989.*** (DCIEM No. 92-10). North York, Ontario: Defence and Civil Institute of Environmental Medicine.

Abstract The military diver performs a wide range of operational duties encompassing ship repair, search and salvage, mine countermeasures and other special operations. Diving can take place in diverse range of water temperatures, depths and durations. The diver is now exposed to deeper, and/or longer profiles under new scenarios and, as a result, thermal limits to performance have once again emerged as the prime limiting factor. Research is being carried out in all aspects of thermal protection. Passive thermal protection, whether wet or dry, is seeing the introduction of new materials and effective clothing ensembles. Active thermal protection is traditionally just the free flow of hot water into a diving suit but is now being approached by new and novel methodologies. It was, therefore, as a result of the renewed interest in diver thermal protection that the concept of this workshop was developed. It was organized under the auspices of the ABCA-10 (America, Britain, Canada and Australia) Information Exchange Program on Naval Diving and its purpose was to bring together representatives from all the components concerned with military diving; the operators who must dive in the various conditions and will know the shortcomings as well as the strengths of a protective ensemble; the manufacturers, who through their own research as well as feedback from the user must produce the protective ensembles; and the researchers, whether basic or applied who through their creativeness develop the concepts and physiological basis for thermal protection.

Nishi, R. Y. (1992). **Design of Decompression Trials - DCIEM experience.** In M. A. Lang & R. D. Vann (Eds.), *Proceedings of the American Academy of Underwater Sciences Repetitive Diving Workshop.* (pp. 311-320). Costa Mesa, CA: American Academy of Underwater Sciences.

Abstract Although statistical significance is desirable in testing the safety of decompression models or tables, it is impossible to conduct enough dives to reach this goal. Decompression model/tables testing is governed more by practical considerations such as the number of dive subjects available, the time available for testing, the facilities available or required, and most importantly, the funding available. Within these constraints, one must design the model, generate the decompression tables from this model, select the profiles to be tested, and conduct the tests. The Defence and Civil Institute of Environmental Medicine has been involved in an active program of table testing and dive profile validation since 1979. Projects have included the evaluation of the Kidd-Stubbs dive computer model (1979), a study of no-decompression dive limits (1980), adapting a dive computer model for oxygen

decompression (1982), development and testing of the DCIEM air tables (1983-1986), and development and testing of new mixed gas (84/16 HeO2 tables) (1986-1991).

Nishi, R. Y., Lauckner, G. R., Hobson, B. A., & Morson, P. D. (1992). ***DCIEM Diving Manual: Part1, Air Decompression Procedures and Tables. (DCIEM 86-R-35).*** Richmond, B.C.: Universal Dive Techtronics, Inc.

Abstract The DCIEM Diving Manual, Air Decompression Procedures and Tables, is a civilian version of Chapter 3, Volume 3 of the Canadian Forces Diving Manual. It includes the complete set of tables - Standard Air Decompression, Short Standard Air Decompression, In-water Oxygen Decompression, Short In-water Oxygen Decompression, Surface Decompression with Oxygen, Repetitive Diving Tables, and Depth Corrections for Diving at Altitude - in both feet of seawater (fsw) and metres of seawater (msw). The text describing the procedures is largely identical with the Canadian Forces version except for the inclusion of depth units in both fsw and msw, and a section on multi-level diving. Also included (in the second edition) are two appendices: the first on nitrox (nitrogen-oxygen) diving with open circuit breathing apparatus; and the second on a modified in-water oxygen decompression table. The manual is published and distributed by UNIVERSAL DIVE TECHTRONICS, INC. (UDT), #201 - 2691 Viscount Way, Richmond, British Columbia, Canada V6V 1M9 under license.

Nishi, R. Y., Morson, P. D., & Dams, W. A. (1992). ***DCIEM Diving Manual: Part 2 - Helium-Oxygen Surface-Supplied Decompression Procedures and Tables. (DCIEM 92-50).*** Richmond, B.C.: Universal Dive Techtronics, Inc.

Abstract THE DCIEM Diving Manual, Helium-Oxygen Surface-Supplied Decompression Procedures and Tables, is a civilian version of the Mixed Gas Section of Chapter 3, Volume 3 of the Canadian Forces Diving Manual. It includes In-water Oxygen Decompression, Surface Decompression with Oxygen, Emergency Procedure Decompression and Abort Tables - in both feet of seawater (fsw) and metres of seawater (msw). The tables are designed for an 84% He/16% O2 breathing mixture. This gives a normal depth exposure limit of 300 fsw (90 msw) and an exceptional exposure limit of 330 fsw (100 msw). A higher percentage oxygen mixture can be used with these tables; however, the maximum depth possible will be reduced by oxygen toxicity considerations. A feature of these tables is the requirement for air decompression from the first stop to the 30 fsw (9 msw) in-water oxygen stop. The procedures parallel as much as possible those developed for the DCIEM air diving tables. Repetitive diving tables and diving at altitude are not addressed for these helium-oxygen tables. This manual forms Part 2 of the complete DCIEM Diving Manual. Part 1 consists of the Air Decompression Procedures and Tables (DCIEM No. 86-R-35, March 1992). The complete manual is published and distributed by UNIVERSAL DIVE TECHTRONICS, INC. (UDT), #201 - 2691 Viscount Way, Richmond, British Columbia, Canada V6V 1M9 under license.

Romet, T. T. (1992). **Comparison of heliox and air as suit inflation gases.** In R. Y. Nishi (Ed.), *Proceedings of the DCIEM Diver Thermal Protection Workshop, 31 Jan - 2 Feb 1989,* DCIEM No. 92-10, (pp. 45-50). North York, Ontario: Defence and Civil Institute of Environmental Medicine.

Abstract It is well accepted that the primary disadvantage of helium based breathing gas also acting as the suit infla-

tion gas is its higher thermal conductivity. Although thermal conductivity of helium is six times that of nitrogen, a helium/oxygen mixture similar to air is only four times as great. It has been further suggested that for each deg. C that the ambient air is below mean skin temperature, the skin will be 0.1 deg. C lower in a HeO2 gas than air. Chamber studies have shown exposure to a helium environment results in a skin cooling, higher ambient temperatures to maintain comfort but no effect on core temperature. This study investigated the differences between HeO2 and air as a suit inflation gas during in-water dives ranging in depth from 36 to 86 msw. In the double blind study neither the divers or investigators were told which gas was provided for suit inflation. Core temperature was determined by rectal thermistor and skin heat flow by heat flux transducers. Results showed resting heat flows were 31% higher with HeO2 as the suit inflation gas (137 vs 102 W/m2) while the peak difference was 61% (190 vs 118 W/m2) at 10 min. The difference remained approximately 50% for the majority of the in-water time. There were no significant differences in core temperatures but skin temperatures were significantly lower ($p<0.05$) at all depths and time points. The greatest differences observed were 2.9 deg. C with steady state differences near the end of immersions of 1.5 deg. C. Absolute values however seldom dropped below 28.5 deg. C except when some water leaked into the suit. Most divers perceived themselves as cool with the helium while rating themselves as comfortable or cool but comfortable with air. The results suggest that while thermal comfort would be improved substituting air for HeO2 as the suit inflation gas, physiologically there were no significant advantages over the depth and time profiles investigated.

Romet, T. T. (1992). **Thermal insulation in various dry and flooded drysuit/pile undergarment combinations.** In R. Y. Nishi (Ed.), *Proceedings of the DCIEM Diver Thermal Protection Workshop, 31 Jan - 2 Feb 1989,* DCIEM No. 92-10, (pp. 75-80). North York, Ontario: Defence and Civil Institute of Environmental Medicine.

Abstract Passive thermal protection in the form of drysuit and undergarment is often the choice during diving operations in the Canadian Forces. Recently, a program has been undertaken to evaluate various suits and undergarments. While manikin or other laboratory techniques may accurately define insulative characteristics of the materials or garments, it was also felt that human trials would provide a better understanding of the inter-relationship between the clothing characteristics and the diver. Seven various dry suits (5 neoprene and 2 non-compressible) and three different synthetic pile undergarments were evaluated. Seven heat flux transducers, placed according to the 7-point scale of Burton were used to measure heat flux from the body from which suit insulations were calculated. Results showed that 7 mm St. Albins neoprene compared to Rubatex based neoprene drysuits provided approximately 15-18% more insulation during immersion at the surface, but with the effects of compression, the differences disappeared with the Rubatex neoprene providing better insulation during all the decompression phases. Insulation of the suits following complete flooding showed a small but significant relationship where suits with a lower initial insulation, generally because of tighter fits, showing the least decrement. The decrease averaged 58% from the unflooded condition. Prolonged immersion at depth, under resting conditions with the various drysuit/undergarment combinations provided between 1.1 and 1.5 Clo of protection. However, for the inactive diver, thermal comfort could not be maintained at a comfortable or cool but comfortable level for periods exceeding 90 min.

Tikuisis, P., & Nishi, R. Y. (1992). **Application of maximum likelihood analysis to repetitive air diving.** In M. A. Lang & R. D. Vann (Eds.), *Proceedings of the American Academy of Underwater Sciences Repetitive Diving Workshop.* (pp. 263-268). Costa Mesa, CA: American Academy of Underwater Sciences.

Abstract The present study examines the application of the method of maximum likelihood to repetitive air dives. The method of maximum likelihood optimizes the parameters of a probabilistic model for the prediction of decompression sickness (DCS). The optimization procedure matches as closely as possible the predicted incidence of DCS to the observed incidence from dive data. The model selected for the present study is based on the supersaturation of nitrogen in two parallel compartments having different time constants and risk factors which are the parameters of the model. The data involves 1299 trials (3811 man-dives) including dives on air and nitrox, and some with 100% oxygen during portions of the decompression. Of these trials, 21 were repetitive air dives of varying depths and bottom times. The mean incidence of DCS for the whole data set was 2.52%. After the model parameters were optimized (time constants of 12.3 and 180 min, and risk factors weighted approximately in the ratio of 1:2), the model was then applied to the repetitive dives for a predictive analysis. The results of this analysis are presented in detail and a comparison is made with the predictions obtained when the bottom time of the second dive is shortened in accordance with the DCIEM Sport Diving Tables. The predicted probability of DCS decreased, but insignificantly; values ranged from 1.2 to 3.8% for the original dives and from 1.1 to 3.2% for the sport dives.

Tikuisis, P., & Ward, C. A. (1992). **Rate of gas absorption by liquids and "surface resistance".** In D. Dekee & R. P. Chhabra (Eds.), *Transport Processes in Bubbles, Drops and Particles.* (pp. 114-132). New York: Hemisphere.

Abstract The common procedure used to determine the diffusion coefficient (*D*) of a gas in a liquid is to expose the liquid to the gas for a period of time, measure the amount of gas absorbed and then determine *D* from a fitting procedure. It is normally assumed that upon exposure, the interphase is instantaneously equilibrated with the gas phase, but this assumption has led to inconsistencies in the values of *D* that are inferred from different experimental techniques. In the case of oxygen dissolving in water, this procedure has led to very small values of *D* being inferred when the exposure time is brief, as compared to the values of *D* obtained when the experimental technique involves longer exposure times. By contrast, when carbon dioxide is dissolving in water, experimental techniques that involve different periods of exposure nonetheless lead to consistent values of the diffusion coefficient. The discrepancy in the value of *D* has been suggested to be caused by "surface resistance". If Statistical Rate Theory is adopted to predict the rate of gas absorption at the liquid-gas interface, the equilibrium assumption can be replaced by an expression for the rate of gas absorption. This rate expression only involves parameters that may be evaluated by independent experimental techniques and when it is applied to examine the experimental data for both of these gases, it is found that a consistent value of the diffusion coefficient is obtained for each of the gases. The results suggest that Statistical Rate Theory gives an explanation for the phenomena that has been associated with "surface resistance".

Weathersby, P. K., Survanshi, S. S., Nishi, R. Y., & Thalmann, E. D. (1992). ***Statistically based decompression tables – VII: Selection and treatment of primary air and N_2O_2 data.*** (NSMRL Report No. 1182 NMRI No. 92-85 .). Naval Submarine Medical Research Laboratory, Groton, CT Naval Medical Research Institute, Bethesda, MD.

Abstract Probabilistic models of decompression sickness (DCS) require high quality data of diving profiles and DCS occurrence to get reliable predictions of the probability of DCS, P(DCS). Over 400 experimental dives performed since 1977 in the U.S., U.K., and Canada were collected, verified, and formatted for use in probabilistic models. In most cases the dive profile precision is within 1 fsw in depth, 30 sec in time, and 0.1 ATA in PO2. DCS outcome and other medical records are of the high quality expected for test dives done in military laboratories. This report describes the data sources, steps used in the review and formatting process, and summaries of the data collection.

1993

Cox, J. P., & Eaton, D. J. (1993). ***Selection of a Gas and Flow Rate for the Bailout Assembly used in the Canadian Clearance Diving Apparatus.*** (DCIEM 93-37). Defence and Civil Institute of Environmental Medicine.

Abstract The Canadian Clearance Diving Breathing Apparatus (CCDA) is a closed/semi closed circuit oxygen/nitrogen minecountermeasures re-breather diving set. Since 1991 a Bailout assembly has been available to the CCDA and by the spring of 1993 all CCDA's held by both Fleet Diving Units had been modified to accept the bailout assembly.
The objective of this investigation was to select which of the four standard oxygen/nitrogen breathing gasses used in NATO could be used with the Bailout without modifications or additional capital expense.
To analyze the data a computer spreadsheet was constructed so that gas flow rates, oxygen consumption, ascent rates, depth changes and other variables could be added or changed throughout a simulated dive scenario.
After looking at the four available NATO diving gasses, the simulation showed that only one of the four gasses, a mixture of 60% oxygen and 40% nitrogen, would be suitable for use as a Bailout gas for the CCDA over the full depth range of 0 to 54 metres. The gas flow rate selected was 10.5 standard litres per minute.

Eaton, D. J., & McDougall, S. A. (1993). ***Semi-Annual Project Review of the Experimental Diving Unit.*** (DCIEM 93-56). Defence and Civil Institute of Environmental Medicine.

Abstract The Experimental Diving Unit (EDU) produced this review for the Diving Task Review Meeting held at the Defence and Civil Institute of Environmental Medicine (DCIEM)from 25 to 28 October 1993. Fifteen projects are included. Nine of these are tasks from National Defence Headquarters. The remainder of the projects come under DCIEM's Diving Systems/R&D Project, 51CD. The report covers work done from May to October 1993, inclusive. Previous work on these projects was reported in DCIEM report No. 93-40.
Although only two more projects were added to the index, the number of sub-projects increased substantially. Development and investigation of an integrated minecountermeasures (MCM) diving system are continuing. The work involves weight harness design, surface supplied diving development, face mask development, research and development of real-time gas analy-

sers, investigations of communications equipment, market searches for diver recovery winches, and research and development as well as quality control of dry suit ensembles. In the CUMA/CCDA in-service engineering project most of the sub-projects are nearing completion. Decompression table development for CUMA continued during the review period with another multi-national dive series. Data from those dives also helped advance the development of a decompression model based on probability theory.

Other areas of study led to the replacement of the in-service Canadian Forces SCUBA regulator with a more cold-resistant regulator that will help reduce the malfunction known as freeze-up. This was an interim measure to help alleviate the freeze-up problem before the completion of the development of a freeze-up resistant regulator, EDU's highest priority project. Development of the regulator continues with the prime contractor, Fullerton, Sherwood Engineering Limited, producing prototypes that are being tested by EDU. Test results to date have been favourable. EDU's plans for simulation and modelling of regulator heat and gas dynamics were delayed because of lack of funding.

Heating divers, especially their hands, was successfully achieved through the use of electrically heated diving gloves. The use of electrical heat is being considered for whole body heating as well. A spin-off of the diver heating problem was the initiation of a new project to develop a multi-environment personal heater based on catalytic combustion of fossil fuels like butane or alcohol. This work is being done under contract by Exotemp Systems Ltd of Stittsville, Ont.

Progress has also been made on the standardization of surface supplied communications systems and on improving the information and equipment available for diving in contaminated waters. Additionally, investigations into the feasibility of using neoprene dosed with metals to improve insulation and diver comfort show promising results.

Carbon dioxide absorbent and carbon dioxide absorbing systems are still of interest as the quality assurance standard for soda lime project has now become involved with a NATO project for carbon dioxide absorbent quality standardization. The submersible emergency life support project continues to examine the feasibility of using lithium hydroxide in the CF's two atmospheric diving submersibles, SDL-1 and Pisces IV.

The newest project is an examination of training and acclimatization effects on divers. Finally, safe diving limits around transmitting sonars have been established and a report completed.

In summary, EDU has a high project load and the resources are often spread very thinly. Nevertheless, staff kept projects on track and achieved measurable goals.

Eaton, D. J., & McDougall, S. A. (1993). ***Semi-annual Project Review of the Experimental Diving Unit Nov 1992 to Apr 1993.*** (DCIEM 93-40). Defence and Civil Institute of Environmental Medicine.

Abstract The Experimental Diving Unit (EDU) in the Human Protective Systems Division (HPSD) (formally the Biosciences Division) of the Defence and Civil Institute of Environmental Medicine (DCIEM) produces semi-annual reviews: one each autumn for submission to the Diving Task Review Committee and a second each spring for submission to the Maritime Command Diving Working Group. Additionally, a third review is submitted to the HPSD Annual Review. Generating these documents requires substantial time and effort. However, the effort produces essential working documents needed during the Task Review and Working Group meetings.

To meet the needs of these meetings but reduce the time and effort expended to pro-

duce the documents EDU attempted to streamline the process over the years. A number of factors helped the cause. The semi-annual reviews and the HPSD Annual Review follow a similar format. The reviews normally cover the same projects and much of the information regarding project details remains the same from one review period to another. Consequently, all the project reviews can follow a standard format.
In previous reviews, each individual project review was updated by the project personnel and these updates were collected and given to the HPSD secretary for typing and formatting. The final reviews were attached to the minutes of the respective meetings as separate annexes. This process led to document control problems that made it difficult to establish the status of the reviews. EDU now produces the document internally.
The Head of EDU's Diving Research and Development Group (H/DRDG) produced this document using Frame Technology Corporation's Framemaker publishing software. Project personnel submit project updates to H/DRDG via electronic mail and the changes are made to the master files. The Framemaker book making utility automatically updates the complete review and the table of contents as required. Each individual project review consists of a project title; tombstone information listing the main project personnel, the start and estimated finish dates, the project coding, and the effective date of the review; the project details including the background, defence relevance, and description; the progress up to the effective date including the reports, publications and presentations made; and the projections for the next review period. This format is very similar to that used in the HPSD Annual Review; therefore, with only a few minor changes to the master files EDU can satisfy the requirements of this third review. The production of the EDU reviews as a single document has reduced the effort required from many person days to 2-3 person days and has made the tracking of the document much simpler.
EDU produced this review for submission to the Maritime Command Diving Working Group held 26-30 Apr 1993 at National Defence Headquarters in Ottawa, Ontario. Fourteen projects are included. Four of these are 1B projects funded as taskings from NDHQ while the remainder come under DCIEM's 2B project, 51CD. The progress covers work done since the last Diving Task Review, 2-5 Nov 1992.

Nishi, R. Y. (1993). **"Tiny Bubbles": A primer on Doppler ultrasonic bubble detection.** *aquaCorps Journal, 5*(1), 24-31.

Abstract A considerable amount of interest in recent years has arisen in Doppler ultrasonic bubble detection and its application to decompression research and diving operations. As a result, there are some misunderstandings about the role of bubbles that can be detected by the Doppler instruments and the relationship between Doppler-detected bubbles and decompression sickness (DCS). The Doppler ultrasonic bubble detector is the simplest, most convenient and most practical method for observing bubbles in humans but it can only detect intravascular bubbles, i.e., bubbles moving through the circulatory system, and requires skilled personnel to use and interpret the bubble signals. An analysis of over 3200 man-dives shows that the risk of DCS is low when no bubbles or only a few are detected. However, for high bubble levels, there is a much higher risk of DCS. In the data set studied, 90% of the cases of DCS were associated with Grades 3 or 4 bubbles. It should be emphasized that intravascular bubbles are not believed to be the direct cause of the signs and symptoms in all cases of DCS. They are, however, an indicator of a high inert gas load in the body and, as a result, their presence reflects the risk of DCS. Dives which produce high levels of bubbles can be considered to have high "de-

compression stress". The primary use of Doppler is as a research tool for post-dive assessment of dive profiles. It cannot be used as a personal decompression monitor to control the rate of ascent for most dives. Unless users are highly proficient in detecting and grading bubbles, there is a large danger of misuse of the instrument and misinterpretation of the results.

Nishi, R. Y. (1993). **Doppler and Ultrasonic Bubble Detection.** In P. B. Bennett & D. H. Elliott (Eds.), *The Physiology and Medicine of Diving, Fourth Edition.* (pp. 433-453). London: W.B. Saunders Company.

Abstract Although there may be many mechanisms associated with decompression sickness, the most probable initiating factor is still believed to be the formation of bubbles. Since bubbles interact strongly with sound waves, considerable research has been done into the detection of bubbles in humans and animals by ultrasonic methods. The ultrasonic scanning method enables the detection of gas bubbles in tissue and the Doppler method the detection of moving bubbles in the circulatory system. This review article deals primarily with the Doppler method, its uses, bubble classification schemes, automatic bubble detection systems, and applications for decompression and other diving related studies. There is a good correspondence between decompression sickness and Doppler-detected bubbles and, as a result, bubbles can be used as indicators of decompression stress.

Tikuisis, P., & Nishi, R. Y. (1993). **Application of bubble models to the prediction of decompression sickness using maximum likelihood.** In R. E. Reinersten, A. O. Brubakk, & G. Bolstad (Ed.), *19th Annual Meeting of European Undersea Biomedical Society,* (pp. 283-286). Trondheim, Norway: SINTEF UNIMED.

Abstract Recent studies on the application of the method of maximum likelihood for predicting the risk of decompression sickness (DCS) suggest that gas washing is exponential and gas without is linear (Parker et al., 1992). These characteristics can be approximated by the formation and subsequent growth of a bubble upon decompression. This study reports on the development of such a bubble model and its application to a series of 2023 man-dives (Parker et al., 1992) involving single and repetitive dives on air and mixtures of nitrogen and oxygen. Depths ranged from 1.75 to 7.09 bars and bottom times ranged from 2.8 to 300.2 min. The overall DCS incidence was 4.93% and time of occurrence information was used (survival analysis). The formation of the bubble was based on the concept of the critical radius (Ward et al., 1982) and the bubble's rate of evolution was based on a linear gas exchange between the compartment and the bubble (Tikuisis, 1981). Fixed parameters included the solubility of nitrogen and the bubble surface tension which were chosen to represent a blood plasma solution. Risk of DCS was based on the integration of the bubble size over time. The best fit using a single compartment of volume 10^{-4} cm^3 was obtained with a risk criterion based on bubble radius and a time constant (for nitrogen gas exchange between the compartment and the ambient condition) of 91.1 min with a SE of 2.6 min.

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51 CD - Diving

1994

Eaton, D. J., & McDougall, S. A. (1994). ***Semi-Annual Project Review of the Experimental Diving Unit.*** (DCIEM 94-30). Defence and Civil Institute of Environmental Medicine.

Abstract The Experimental Diving Unit (EDU) produced this review for the Diving Task Review Meeting held at the Defence and Civil Institute of Environmental Medicine (DCIEM) from 9 to 12 May 1994. Twelve projects are included. Seven of these are tasks from National Defence Headquarters (NDHQ). The remainder of the projects come under DCIEM's Diving Systems/R&D Project, 51CD. The report covers work done from November 1993 to April 1994, inclusive. Previous work on these projects was reported in DCIEM report No. 93-56.

Two projects in EDU, development of a freeze-proof regulator and decompression tables for the Canadian Underwater Mine-countermeasures Apparatus (CUMA), continue to occupy the majority of the unit's time. Regulator development involved iterative testing and modification of two prototypes while two, four-week dive series were completed to add 173 more human exposures to the data base required to validate the CUMA decompression model and tables.

The development of an integrated system of equipment for mine-countermeasures diving integrated well with the CUMA decompression table validation. During each dive series components, such as new weight harness prototypes or dry suit samples, were included in the dives so that development could continue in parallel with the table validation. Another project which dovetailed well with the CUMA decompression work was the development of the hand heating system under the Clearance Diver's Supplementary Heater project. Prototypes were evaluated during the CUMA decompression dives. This project has expanded to include whole body heating and electric suits for this purpose were obtained to compare their performance against the standard hot water suit.

In other NDHQ sponsored tasks, the examination of lithium hydroxide as a carbon dioxide absorbent in the Submersible Diver Lockout (SDL) led to a recommendation to discontinue its use in favour of traditional soda lime. A field trial of various dry suits provided the necessary data to formulate a suit specification for use in self-contained diving in low level contaminated water. The study of the effect of the complement enzyme system on decompression sickness began with initial literature review and the training of a technologist to perform blood assay work.

Projects coming under DCIEM 51CD tested the hypothesis that exercise during the decompression phase of a dive can reduce decompression stress through a series of 129 human exposures. Work and meetings of the researchers developing a common model for decompression with helium/oxygen breathing mixtures progressed the establishment of a master data base to use for model development and validation. EDU staff built and field-tested prototypes of equipment needed to standardize surface-supplied diving communications systems. Quality assurance of soda lime for diving apparatus continued to involve international attention as a Study report was tabled at the NATO Underwater Diving Working Party Study. The investigation of thermometal neoprene concluded with a DCIEM report and final contact with the manufacturer to identify the varieties of materials available.

In the coming six months, work will conclude on the SDL carbon dioxide absorbent, self-contained, contaminated water diving ensemble and surface-supplied diving communications standardization. This will increase resources available for other projects

such as the mine-countermeasures diving system development and clearance diver's supplementary heating. Another new project involving the investigation of closed-circuit rebreather diving apparatus is also expected to commence during the next review period.

Tikuisis, P., Gault, K. A., & Nishi, R. Y. (1994). **Prediction of decompression illness using bubble models.** *Undersea Biomed. Res., 21,* 129-143.

Abstract The method of maximum likelihood was applied to models of bubble formation and evolution against data involving decompression illness (DCI). Equilibrium and non-equilibrium gas kinetic models were tested under the constraint of a finite tissue volume. The equilibrium model (leq), where the internal gas of a bubble is in partial pressure and mechanical equilibrium with the gas dissolved in tissue, assumed formation of a bubble upon any gas supersaturation. The non-equilibrium model (neq), where mechanical equilibrium is maintained but the exchange of gas between the bubble and tissue is governed by a rate constant, assumed formation of a bubble at the metastable equilibrium state which requires a specific degree of gas supersaturation. In addition, another version of bubble evolution based on the diffusivity of gas in tissue (vl) was tested under similar finite volume constraints. Model parameters included liquid surface tension, the gas exchange rate constant, gas solubility, and the tissue time constant. The risk of DCI was based on the bubble radius (R) raised to powers ranging from 0 to 6. The data included 2,023 man-dives in 630 different dive profiles of air and nitrox gas mixtures with depth ranging from 1.75 to 7.09 bar and bottom time ranging from 2.8 to 300.2 min. There were 97 occurrences of DCI and 27 occurrences of marginal symptoms. Predictions of the neq and vl models were quite similar and suggested that the tissue primarily responsible for bubble formation leading to DCI in the present analysis has a perfusion rate of about 4.0 ml blood · 100 ml^{-1} · min^{-1}. The best fit of the data for a single compartment of 10^{-4} ml vol was obtained with the leq model and a risk based on R^4, and an estimated time constant of 95.6 ± 9.8 min.

Tikuisis, P., & Nishi, R. Y. (1994). ***Role of Oxygen in a Bubble Model for Predicting Decompression Illness.*** (DCIEM 94-04). Defence and Civil Institute of Environmental Medicine.

Abstract A mathematical model is developed for predicting the incidence of decompression illness (DCI) in dives involving nitrogen and/or helium. The model is based on the growth of a bubble that is predicted to form upon a condition of gas supersaturation. The model compartment is assumed to be perfusion-limited, hence, the uptake and elimination of each gas is distinguished by its partition coefficient (solubility ratio of blood to tissue). Bubble evolution is predicted by assuming either a diffusion limitation in a gas transfer or complete equilibrium between the gas and tissue phases. An oxygen effect is implemented by 1) considering the possibility that oxygen may contribute to the bubble in a gaseous form when its ambient level exceeds an estimated threshold and 2) taking into account the vasoconstrictive response induced by high levels of oxygen breathing. Risk of DCI is hypothesized to increase as the time-integrated bubble size increases. The model parameters described above were calibrated using the method of maximum likelihood against a total of 2,378 man-dives (715 involving helium) with a 4.56% incidence of DCI. The best fit of the data was obtained with the equilibrium approximation and the combined oxygen effect. Estimated parameter values were a blood perfusion (Q) of 0.041 ml blood · ml^{-1}

· min $^{-1}$ and Ostwald gas solubilities of 0.0344, 0.0125, and 0.0609 for nitrogen, helium, and oxygen, respectively, which are within the physiological range. The estimated parameters pertaining to the oxygen effect suggest that Q can be reduced by up to 52% with high levels of oxygen breathed and that oxygen contributes to the bubble's presence when its arterial tension exceeds 0.46 bars.

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The References and Abstracts of all the papers published by the Human Protective System Division, DCIEM, 1986 to March 1995.

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